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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

IMPROVED PLANNING AND PRODUCTION CONTROL

U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION

IN COOPERATION WITH
BATH IRON WORKS CORPORATION

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SYNOPSIS

SYNOPSIS

1. Objective - The basic objective of Task O-2 Research was to identify potential improvements to planning and production control functions for commercial ship constructioN and to evaluate the impact of these improvements on reducing shipbuilding costs.

2. Method - After surveys of domestic shipyards, related industries, and the literature, it was concluded that use of Industrial Engineered standards in planning and production control would be the most fruitful avenue of investigation; all subsequent research focused, therefore, on the use of standards in the planning and production control function.

3. Scope - Three types of standards were evaluated:

   a. Historical Standards, i.e., standards derived from prior experience and typically expressed in terms of steel tonnage such as tons per week. This type of standard is now in common use throughout the U.S. Shipbuilding Industry.

   b. Imported Standards, i.e., standards developed in related industries and adapted for use in the shipyard. These standards were typically expressed in terms of process rates, such as inches" of weld per minute.

   CO Engineered Standards, i.e., standards derived from physical measurement of the processes (burning, fitting and tacking, welding, etc.) involved in production. Like Imported Standards, these are expressed in terms of process rates but these standards recognize the unique characteristics of the operation at that shipyard on a particular product.

The experimental setting where standards were evaluated was the steel fabrication plant.

4. Experimental Results - Improvements in productivity and schedule adherence resulting from use of engineered standards in place of traditional Historical Standards were dramatic. Measured reduction in cost of fabrication-operations for thirteen erection units in each of two ships in a four ship contract ranged between tWenty and thirty percent. Schedule adherence for these units improved from an average of four weeks late to

zero weeks late and from a maximum time late of seven weeks to two weeks maximum for any unit. In every case, performance improvements when using engineered standards were superior to . improvements when using imported standards. Imported Standards had to be discarded early in the experimental period because of their unreliability.

5. Cost-Benefit Analysis - By projecting experimental results obtained from the sample of thirteen units on which engineered standards were applied for each of the two ships, the costs and benefits were determined to be:

(a) The cost ($63,000) of developing and applying engin-

(b) The savings for the second and subsequent ships would approximate $270 thousand per ship.

6. Conclusions - On the basis of the experimental results achieved it is concluded that:

(a) The use of Engineered Standards in shipyard planning and production control will significantly improve schedule compliance and will increase shipyard productivity. Indeed, the contributions to cost reduction measured by the research far exceeded the rather conservative projections made early in the project.

(b) Costs of developing and applying Engineered Standards can be fully recovered on a single ship construction project and still yield net savings in fabrication costs.

(c) Shop labor will cooperate fully with the use of Engineered Standards in planning and production control if proper groundwork is laid.

(d) A fully informed and supportive shipyard management is essential to effective use of Engineered Standards.

7. Recommendations -

(a) Research in the use of Engineered Standards should be extended beyond steel fabrication to panel, assembly, erection and outfit operations.

(b) Value of Engineered Standards in higher level management functions such as bid estimating should be

analyzed.

(c) Use of computer-aids to assist planners in the maintenance and application of Engineered Standards should be evaluated.

(d) An introduction and promotional program on use of Engineered Standards should be prepared and presented to top level shipyard management throughout the industry.

(e) A Planning and Production Control Handbook tailored to shipyard use should be prepared.

FOREWORD

This study was undertaken as part of the Ship Producibility Program managed by Bath Iron Works Corporation. The Ship Producibility Program is part of the National Shipbuilding Research Program originally defined by the Ship Production Committee of the Society of Naval Architects and Marine Engineers. The research was funded jointly by the Maritime Administration and the U.S. shipbuilding industry under a cost-sharing arrangement. The Improved Planning and Production Control Study was selected as a high priority task at a conference of shipbuilding management personnel held at Annapolis, Maryland in 1973.

The purpose of this report is to document results of research accomplished -- both positive and negative findings. It is not intended to be a treatise on shipyard Planning and Production Control. A more comprehensive manual on this subject is planned to round-out and complete efforts under Task O-2.

The work summarized in this report was accomplished by personnel in the Industrial Engineering Department of the Bath Iron Works Corporation with subcontract assistance from the following firms: Collett, Gatenby and Hatfield of Arlington, Virginia conducted the literature search; Management Associates of Jacksonville, Florida assisted the specification of standards; and Corporate-Tech Planning Inc. of Portsmouth, New Hampshire and Waltham, Massachusetts assisted in the preparation of the report.

Special acknowledgement is given the Advisory Council for their evaluation and important comments. This group, composed of representatives of the marine industry, provided valuable guidance and direction to the early phases of this project. An. earlier draft of the report was reviewed in depth by the council. This final version reflects all of the council's suggestions and comments which led to a rather extensive restructuring of the material originally contained.

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I. TASK 0-2 RESEARCH GOALS AND OVERALL PIAN

1.1 Background - Task Origins

To help the U.S. shipyards meet the challenges set forth in the Merchant Marine Act of 1970, the Maritime Administration initiated the National Shipbuilding Research Program as a joint Industry/Maritime Administration venture to develop ways and means of reducing costs of ship construction in U.S. shipyards. The Ship Producibility Research Program, under the management direction of the Bath Iron Works Corporation, is one of five major projects currently sponsored under this Research Program.

Definition of specific tasks within the Ship Producibility Program was accomplished at a conference of senior personnel from twelve U.S. shipyards at Annapolis in 1973, who reviewed the economic and technical merits of one-hundred-twenty-seven task suggestions submitted by representatives throughout the U.S. shipbuilding industry. The twenty-nine tasks (Table I-1)

RESULTS FROM ANNAPOLIS CONFERENCE		
CANDIDATE TASKS EVALUATED		**127**
TASKS SELECTED FOR SHIP PRODUCIBILITY PROGRAM:		
"O" TASKS - IMPROVED SHIPYARD OPERATIONS		
"S" TASKS - DEVELOPMENT AND USE OF STANDARDS	**1;**	
"P" TASKS - LOW COST PRODUCIBILITY FEATURES	**2**	
"D" TASKS - IMPR0VES DESIGN PROCESS	**6**	
TOTAL SHIP PRODUCIBILITY RESEARCH TASKS		**29**

TABLE I-1: SHIP PRODUCIBILITY RESEARCH PROGRAM TASK ORGANIZATION. These tasks were selected to develop cost reductions in ship construction.

which survived the rigorous screening process form the substance of the Ship Producibility Research Program.

Improved Planning and Production Control which falls within the "O" Task Group was identified by the conference as one of the most promising areas for investigation. Research conducted since the Annapolis Conference has confirmed conference opinion. Indeed, cost reduction opportunities provided by the Improved Planning and Production Control techniques outlined in this report can make one of the most significant contributions to achieving the subsidy reduction objectives of the many research projects within the Ship Producibility Research Program.

1.2 Purpose And Focus Of Task O-2 Research

Tasks within the "O" group in the Ship Producibility Research Program differ from most other research sponsored by the National Shipbuilding Research Program in that these tasks are primarily concerned with reducing the cost of ship construction by <u>improving the utilization of existing facilities and resources</u>. Other research projects have been concerned with improving the physical processes of construction or developing new facilities and tools which have higher productivity coefficients than the technology they are intended to replace.

The effectiveness with which resources are used is largely dependent on:

1. <u>PlanninG</u> - which determines how the work is to be accomplished, what resources are to be used (material, labor, facilities, and time), and the

sequence in which work is to be accomplished;

2. Scheduling - which specifies when the work is to be completed and thus determines time-phased load imposed on the work force and facilities; and

3. Collecting and evaluvating resource expenditure information - which monitors progress and resource expenditure against schedule and budget and imposes corrective measures when needed.

Improving utilization of resources to reduce shipbuilding costs involves improving the effectiveness of these three functions. The specific goal of the O-2 research was to determine the extent to which these functions could be improved through the use of engineered standards in the planning and scheduling processes.

1.3 Plan For Task O-2 Research

Task O-2 research was divided into five separate phases with the relative distribution of effort as follows:

a. Survey of planning and production control methods in current use in domestic and foreign shipyards as well as in related industries (5% of total research effort).

b. Review and analysis of survey results and preparation of a plan for evaluating the more promising techniques in planning and control of ship construction work (5% of total research effort).

c. Experimental application of the selected planning and production control techniques in actual shipyard operations (75% of total research effort).

d. Analysis of the costs of developing and using standards in planning, scheduling and monitoring functions and their impact on reducing shipbuilding costs (5% of research effort).

e. Analysis of results and preparation of a technical report to disseminate results of the research throughout the shipbuilding industry (10% of research effort).

1.4 Organization Of This Report

This Section (I) describes the research goals and the overall plan for achieving those goals.

Section II introduces the basic planning and production control concepts used throughout the body of the report. The research phase of the study consisted of an experimental evaluation of three different types of standards applied to planning and production control of steel fabrication operations: (a) Historical Standards, (b) Imported Standards, that is, standards taken from outside sources and applied to steel fabrication operations within BIW[1]; and (c) Engineered Standards, that is, standards developed from physical measurement of the unique production processes used within BIW.

[1] Bath Iron Works, Corporation, 700 Washington Street, Bath, Maine 04540.

Section III discusses Historical Standards in planning and production control. Historical Standards constitute the base-line against which the other types of standards were evaluated.

Section IV presents results of experiments with Imported Standards.

Section V presents results of experiments with Engineered Standards.

Section VI contains the conclusions and recommendations.

During the course of the research, it was concluded that standards could be used effectively in other shipyard management functions. Appendix A to this report summarizes these additional uses of standards. Technical details on development and application of specific engineered standards employed in the research are contained in Appendix B.

Appendix C is a synopsis of the literature and shipyard surveys. It was from these surveys that the Task 0-2 Team concluded that the bulk of the O-2 research should be directed toward an evaluation of standards in shipyard planning and production control functions. Appendix C, therefore, provides background information which may be found useful in interpreting the significance of the results summarized in the body of the report.

SECTION II

BASIC CONCEPTS

II. BASIC CONCEPTS

2.1 Planning

In its most general sense, planning is the process of determining how an objective is to be achieved. It identifies the specific, subordinate tasks to be accomplished, the sequence in which-they are to be accomplished and the resources that are to be applied.

The objective identifies the end product which is to be produced as the result of the application of the plan. In a ship construction project, the end product is, of course, the ship itself. The objective is defined by the set of plans and specifications for the ship. Plans and specifications, thus , constitute the basic inputs to the planning process.

Resources which the planner must consider are material, labor, facilities, and time. For each of these general types of resource, the planner must identify the particulars of the resource required and establish the budgets which allocate the amount of each resource to be applied. For material, the specifics are the individual material items identified by plan and piece number, vendor part number or material type: the budgets are the amounts (or quantities) of each item to be used. Material specifics and budgets in combination form the bill-of-material for the task. Identifying the specifics of the labor resource includes identifying the skills (crafts, trades) to be used and the budgeted hours for each. Similarly the specifics for major facility requirements must be identified.

Only recently has time been recognized as a resource. But it is and must also be considered in the planning process.

Time budgets are assigned to each task within a project by specifying the <u>duration</u> within which all work covered by the task is to be completed.

Task durations are not to be confused with schedules although they are primary inputs to the scheduling Process” Scheduling is the process of assigning calendar dates to the beginning and ending events for each of the tasks; task durations set during planning are calendar independent.

Shipyards vary as to responsibility assignments for task durations. In some cases it is the planners’ responsibliity; in others the responsibility of the schedulers. In either case, however, it is a <u>planning</u> function and is so treated throughout this report.

To establish resource budgets (material, labor, facilities and time), the planner must first analyze the content of each task and then estimate the amount of each resource required. In estimating the amounts, he uses rules. These may be explicit rules in which case they are <u>standards</u>; or they may be implicit rules which the planner “carries in his head” and applies in accordance with his intuitive appreciation of the job. Task O-2 research was concerned only with the application of explicit rules, i.e. , standards, in shipyard planning and production control.

In conducting this research, it was convenient to distinguish between three types of standards in accordance with the manner in which they were developed. .

First there are <u>Historical Standards</u>. These are standards

developed on the basis of prior experience. They may be expressed in a variety of ways, but in the U.S. shipbuilding industry they are usually expressed in terms of hours-per-ton, tons-per-week, or some similar form.

Second, there are Imported Standards. Imported standards are standards developed outside the shipyard and "imported" into the shipyard for internal use. These standards may include rate tables generated by a machine manufacturer, or they may be standards developed by another company or industry.

Third, there are Engineered Standards. These are standards developed within a company by physical measurement (using industrial engineering techniques) of the processes involved in producing the products specified as the output (objectives) of the various tasks.

The primary purpose of the Task O-2 research was to determine the relative effectiveness of each type of standard in shipyard planning and production control. Planning in almost all U.S. shipyards uses Historical Standards. Thus the specific objective of the O-2 research was to evaluate the potential improvements offered by Imported and Engineered Standards. In this regard, the motive for considering Imported Standards was largely an economic one -- namely that use of Imported Standards would avoid the cost of engineering them in-house.

2.2 Production Control

duction plans are properly executed. Production control

includes the scheduling function, that "is, the assignment of calendar dates to each task identified in the production plans. In establishing production schedules, schedulers must consider existing workloads on labor and facilities. In doing so they must consider all projects active in the shipyard; therefore schedulers have a total shipyard orientation whereas the ship construction planning function has a single project or contract orientation.

In addition to scheduling, the production control function has a monitoring responsibility. This responsibility includes monitoring of resource expenditures against established plans (budgets) and monitoring work progress against schedules. This monitoring function provides the feedback link (Figure II-1) essential for effective management control of shipyard operations.

2.3 Interrelationships Between Planning And Production Control

Planning and production control were presented above as independent operations. They are not. Every plan should make efficient use of facilities and labor and therefore should imply an efficient schedule. The schedule must be capable of implementation and thus it must take full account of the workloads imposed on the facilities and on the labor force. Also management objectives must be achieved. There is, therefore, continual interaction between objective setting, planning, and scheduling operations (as reflected by the arrows at the left in Figure'II-l) before an integrated and acceptable set of objectives, plans and schedules can be firmly established and implemented.

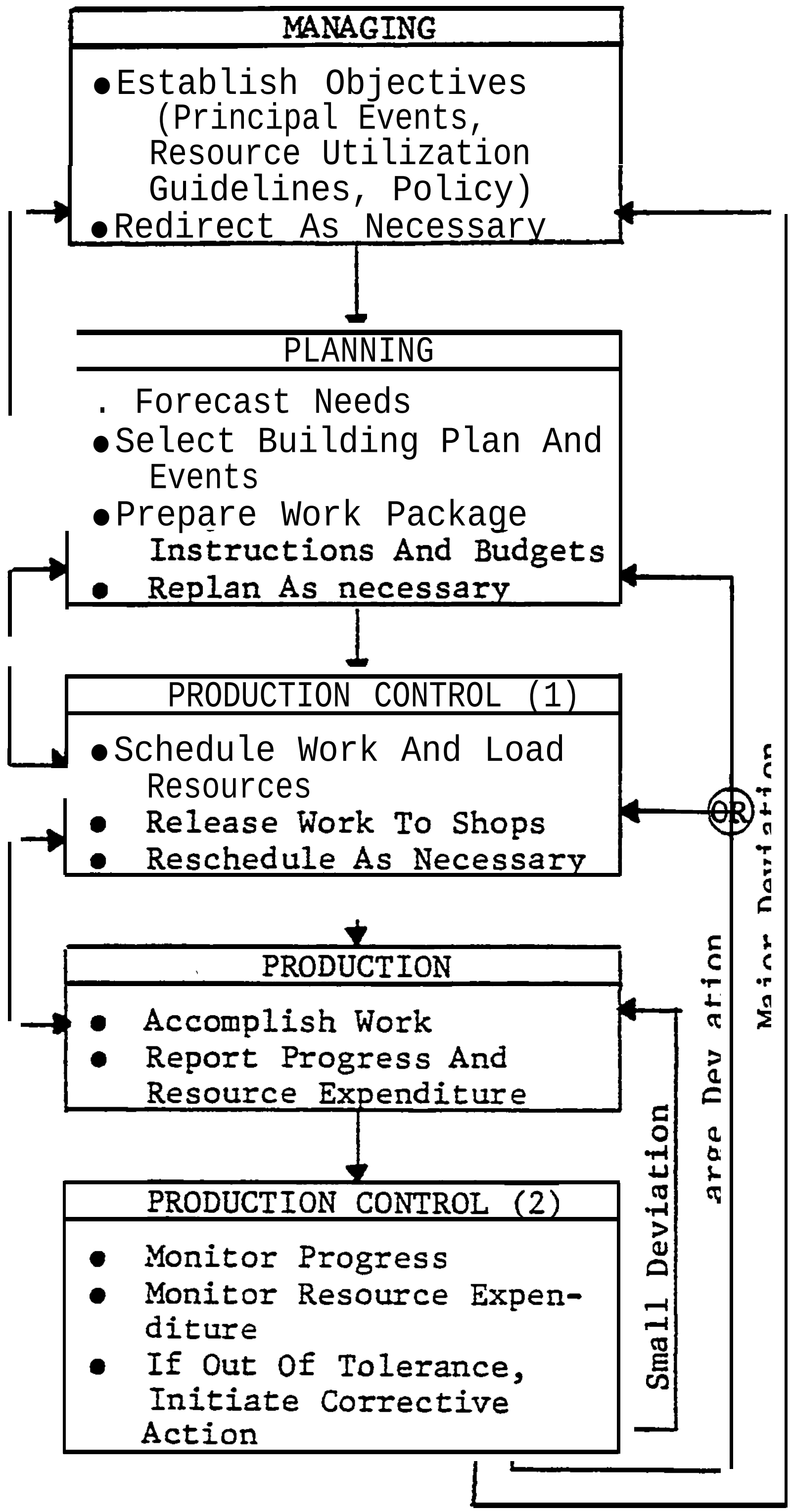

FIGURE II-1: RELATIONSHIPS BETWEEN PLANNING, PRODUCTION CONTROL, PRODUCTION, AND MANAGEMENT

Similarly, after objectives, plans and schedules have been established, they may require modification as work progresses. If out-of-tolerance conditions are observed, adjustments must be made to objectives, plans, and schedules as reflected by the arrows at the right of the Figure.

It is of interest to note that the more reliable the plans and schedules, the fewer out- of-tolerance conditions will arise, thereby not only improving the efficiency of the productive function but also reducing the “fire fighting” burden on supervisory, production control, planning and management personnel. Improving the reliability of the plans and schedules thus has favorable impact throughout the shipyard. It was an objective of the Task o-2 research to determine to what extent this was possible using Imported and Engineered standards to improve the accuracy and reliability of the labor, facilities and time budgets developed in the planning process.

SECTION III

HISTORICAL STANDARDS AND CURRENT PRACTICE

III. HISTORICAL STANDARDS AND CURRENT PRACTICE

3.1 Experimental Setting

Since the experimental evaluation of different approaches to planning and production control was to be conducted in a hands-on shipyard environment, it was necessary to select an appropriate area within a shipyard to conduct the experiment. After considering several alternatives the steel fabrication plant was selected. Several factors contributed to the decision to conduct the initial tests there. The plant has a very capable work force of about 200 craftsmen with a history of good labor relations. It is separated geographically and managerially from the other functions in the shipyard. The Plant Manager has responsibility for all the crafts that work there. He was interested in the project and participated in the development of the task. The data developed for the steel fabrication plant also has direct applicability to many other operations. For example, all the welding processes used throughout the shipyard are practiced there. Consequently it was believed that the same process standards could be applied in other production areas in the shipyard if adjustments were made to accommodate different working conditions such as distances and access.

In addition, the first and second level supervisors were very conscientious about quality and workmanship. At first the supervisors were seriously concerned that the quality would suffer because of the imposition of. standards. However, several tests were conducted to prove that the standard times

were established with workmanship in mind and that quality need not be compromised just because the work was being measured. Standards were set at times which allowed the craftsman to perform the work to the published quality standard.

Finally, there is much greater similarity between steel fabrication operations in different U.S. shipyards than in assembly, outfit and erection operations. Therefore, it was believed that experimental results in the fabrication area would be more readily transferrable and of greater interest to other shipyards.

A brief synopsis of functions performed within the steel fabrication plant will help put the experiment itself in proper perspective. Functional flow of material and sequence of processing operations is shown in Figure III-1.

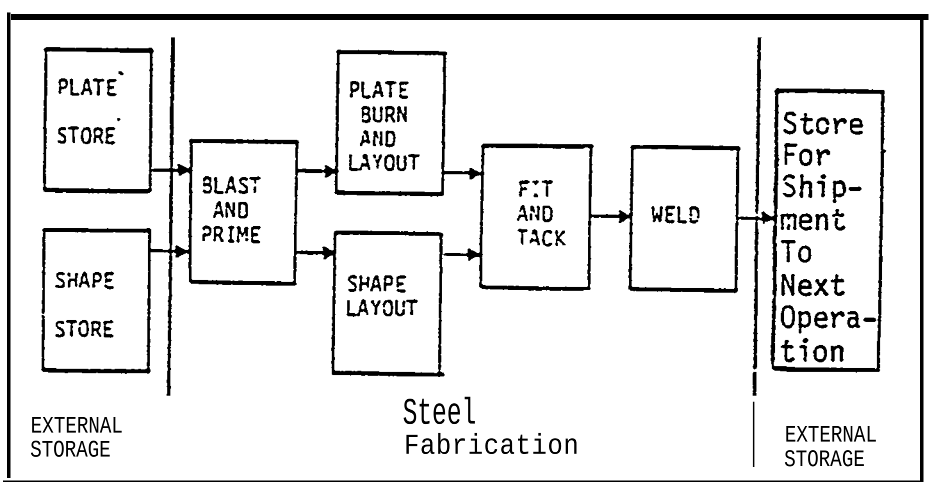

FIGURE III-1 : PROCESS SEQUENCE WITHIN STEEL FABRICATION PLANT

Specific operations performed within this plant include:

- Initial receiving and storing of plates and shapes.
- Blasting and then coating with a weldable preconstruction prime.
- Optical, numerical control and hand oxygen-fuel gas cutting.
- Forming.
- Small part assembling (panels, foundations, webbs, to a maximum of 20 tons, and approximately 8′ x 8′ x 60′ in size).
- Welding.
- Some aluminum fabricating.

Size and weight of steel output is restricted to limits set for overland transportation to assembly areas on the waterfront. Nominal planned capacity of the plant is 640 tons-per-week.

The steel fabrication plant traditionally used Historical Standards for planning. These formed the baseline against which the two alternatives, Imported Standards and Engineered Standards, were evaluated. The experiment was conducted on a series of four identical 20,000 DWT cargo ships. The first two ships in the series were planned and scheduled using Historical Standards; Imported Standards and Engineered Standards were applied midway through fabrication operations on the third ship; and Engineered Standards only were applied during the early fabrication operations on the fourth ship.

3.2 Historical Standards In Planning And Scheduling

Historical Standards, the traditional method for planning, scheduling and production control of ship construction operations, formed the point of departure for the experiment. Accordingly, a brief review of how Historical StandardS are used for planning and production control within the steel fabrication plant is in order.

The basic instrument of management control within the shipyard is the work package. For steel fabrication operations, the work package consists of all parts required for an erection unit. An erection unit typically, because of material handling limits, does not exceed 200 tons. A single fabrication work package may produce several hundred different parts, each of which will be identified with a plan and piece number. Central planning has responsibility for assigning budgets and schedules to the work packages. Planners within the steel fabrication plant have responsibility for budgeting and scheduling operations within the plant.

Establishing fabrication work package labor and machine hour budgets and scheduling work packages through the steel fabrication plant are conducted as two semi-independent operations. The controlling construction schedules are typically established first. These are used not only for scheduling production but also for scheduling planning operations so that work package plans will be available to meet scheduled production . start dates.

3.2.1 Scheduling

Fabrication schedules are set as follows. The Master

Schedule (Figure III-2) contains the principal contract events such as start erection of first unit, launch, complete outfit, trials, etc. These events set the basic framework within which all subordinate activities and events are set.

The unit erection schedule is the next level of scheduling detail. Standard back-off factors are applied to events in the unit erection schedule to establish completion dates for each assembly within a unit, and completion dates for fabrication work packages for all pieces in each assembly as shown in Figure III-2. Standard back-off factors are shown in the figure as T_F for fabrication and T_A for assembly. The time <u>allowed</u> for fabrication, T_F, is somewhat greater than <u>actual</u> predicted fabrication time D_F so that small delays in completing fabrication of the work package will not impact schedules for successor activities. TS represents this safety time.

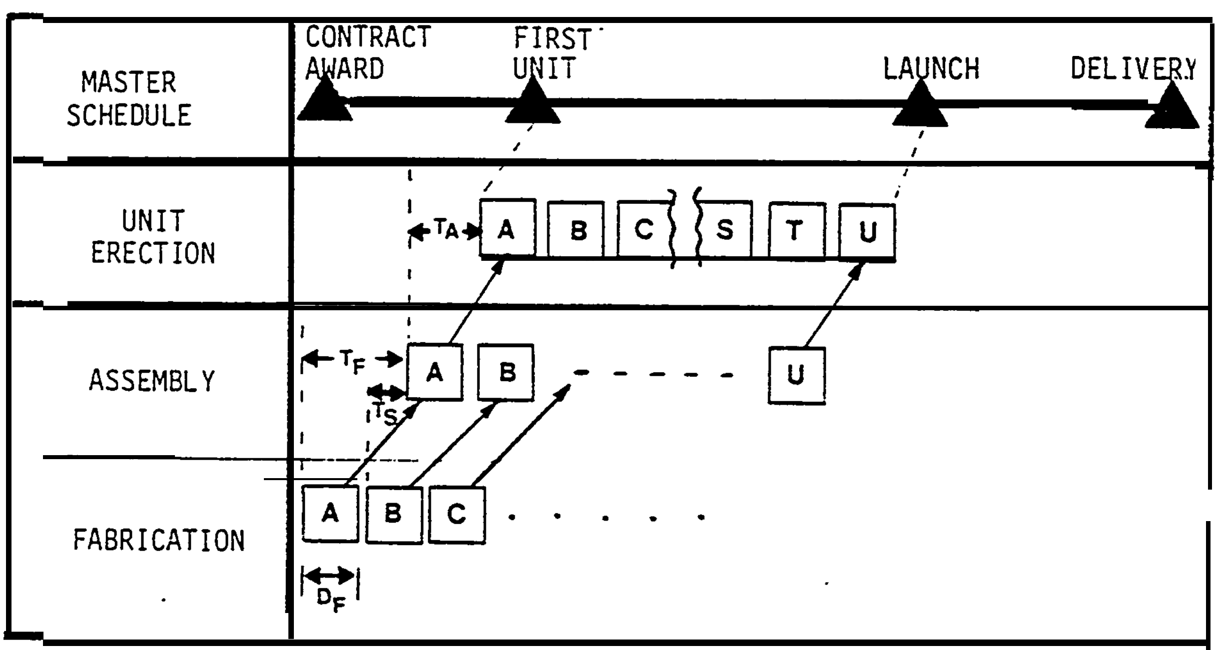

FIGURE III-2: FABRICATION WORK PACKAGE SCHEDULING USING SET BACK TIMES T_A FOR ASSEMBLY AND T_F FOR FABRICATION

he only dates for fabrication operations set by central planning are fabrication completion dates, (e.g., finish weld and move to storage). No dates are set for fabrication of pieces themselves within the shop. These are set by the fabrication plant planners.

Given the fabrication work package (i.e., unit) scheduled completion date, the fabrication plant planner schedules using the rule that one week is allotted for each fabrication operation required (Figure III-3). An extra week is allowed if a unit is particularly complex. Thus he arrives at a latest start date. Also he figures the throughput weight of the units to make sure that each week the shop will start enough steel to meet the 640 ton-per-week goal.

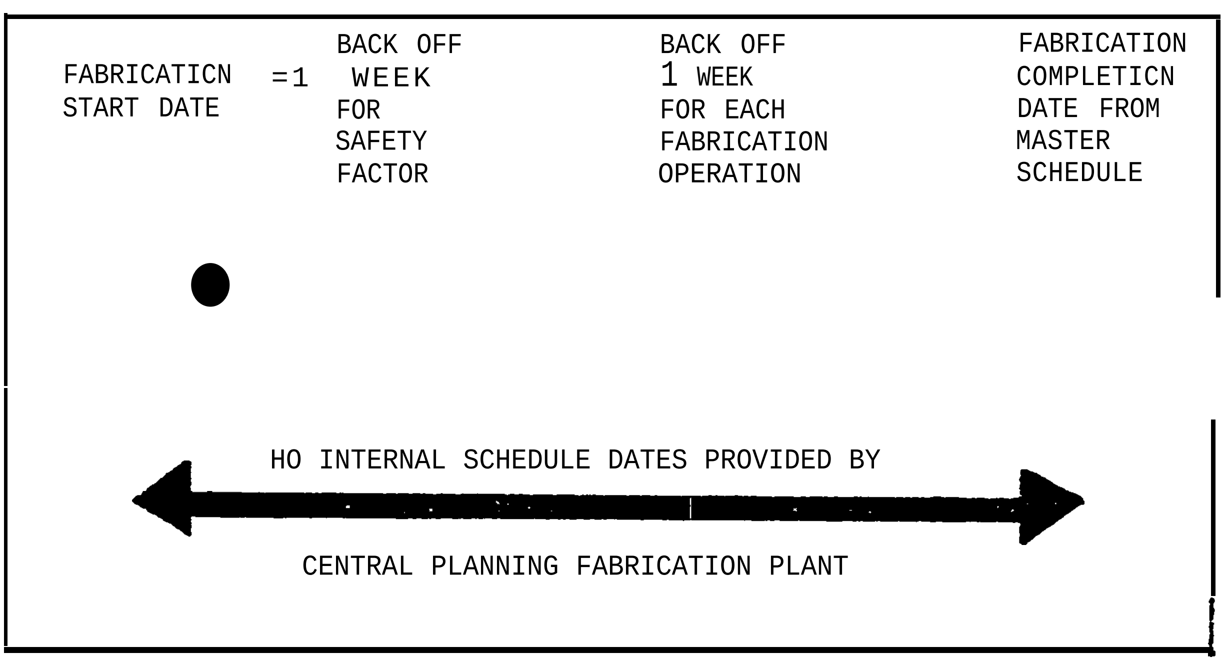

FIGURE III-3: FABRICATION DATES EVELf2PE!l BY FABRICATIOi4 PLANT PLANNERS FROM CENTRAL PLANNING COMPLETION DATES

Each week's schedule is also examined to make groupings of plates by coating type. A blast/paint sequence sheet is prepared each day, which specifies the sequence of operations for the Blast/Paint Line. Plates are blasted and primed following this schedule and stored in a buffer area to feed follow-on operations.

The burning machine supervisor schedules the jobs on the burning machine in such a way that plates requiring the same torch set-up (tip size, bevel, gas pressure, etc.) are run sequentially. This may not be the same sequence followed on the Blast/Paint Line, but the buffer stock of primed plates permits resequencing of plates without interrupting flow through the burning machines (Figure III-4).

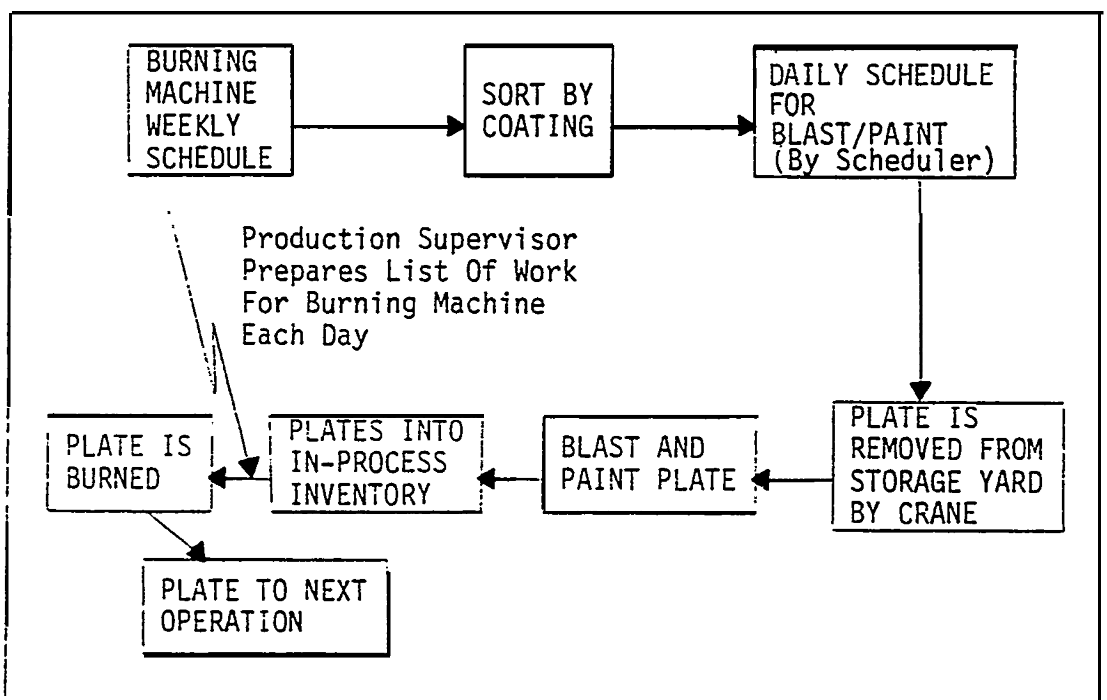

FIGURE III-4: MICRO-SCHEDULING OF BURNING OPERATIONS WITHIN FABRICATION SHOP

The load on the burning machines is calculated using a single value of about 1.7 machine hours per plate. If the load exceeds capacity, an attempt is made to start the processing earlier. After a plate is burned, all follow-on operations are scheduled by the first and second level supervisors.

As the completion dates for the fabrication work packages approach, the plant manager generates an expedite list and extra effort is put on potentially late units.

3.2.2 Budgeting

Historical data is used to budget the steel fabricating plant at two levels of detail. The first and most fundamental is gross plant load. This is total facility throughput-per-week. Records kept on previous contracts cover gross throughput in tens-per-week. However, some adjustments of the data are required because the product mix (Figure III-5) varies from time-to-time. It is necessary to identify the man-hours involved in each type of work. A man-hour-per-ton figure was available for commercial ship construction. More complicated rules are used for Navy work. The budgets for industrial work are derived from the manhours used in the bid. These numbers are generally prepared in considerable detail. The required average weekly throughput for the fabrication shop

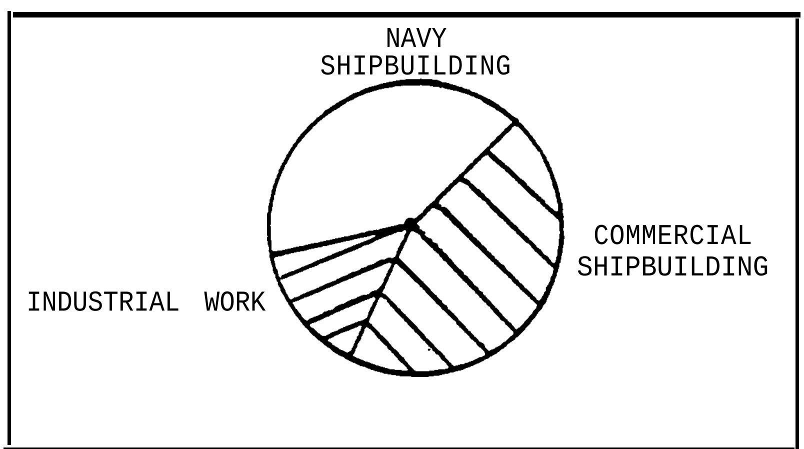

FIGURE III-5: TYPES OF WORK NORMALLY PERFORMED IN THE FABRICATION SHOP

is calculated by combining the dates from the schedule for industrial work and the major milestone dates and the tons-per unit.

3.3 Observations On Use Of Historical Standards

Planning and scheduling by means of Historical Standards is a top-down planning process whereby work involved in constructing the ship is sub-divided into a tree type structure. Work package durations and budgeted hours are estimated by means of tonnage derived rules. Steel tonnage of the fabrication work package is multiplied by a historically derived productivity factor of man-hours-per-ton to determine total man-hours to process the work package. Other than the man-hours-per-ton factor derived from long term statistical averaging of prior experience, no analysis of subordinate job content is attempted.

Work package durations are established by applying the simple rule that one week is allotted for each distinct process step involved, for example, one week to accomplish all welding, one week for all fitting and tacking, one week for all burning, etc. Fabrication work package scheduled completion dates are set by central planning to match needs of the erection schedule. Fabrication work package scheduled start dates are specified by fabrication shop planners by backing-off from the scheduled completion date the number of weeks required for the process steps.

Although not explicitly recognized by the scheduling and budgeting rules, both labor expenditures and actual schedule durations are random variables which have a pronounced variation about their historically determined means D_h (Figure III-6).

If the mean of the distribution is equal to the schedule duration, and there is wide dispersion to the distribution, as many jobs will be finished early as will be finished late. Anticipated lateness is formally accommodated by including a safety factor, typically one or two weeks in the scheduled duration (D_s in Figure III-6). Even so, a significant percentage of the work packages will either be completed late or will require unplanned overtime to meet completion schedules.

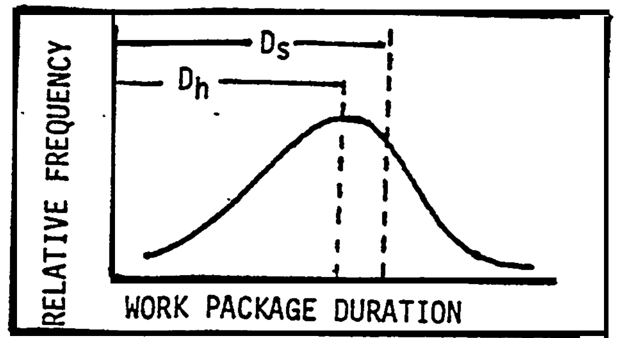

FIGURE III-6: REPRESENTATIVE DISTRIBUTION OF WORK PACKAGE DURATIONS

Figure III-7 is representative of schedule adherence problems associated with the use of historically derived tonnage rules.

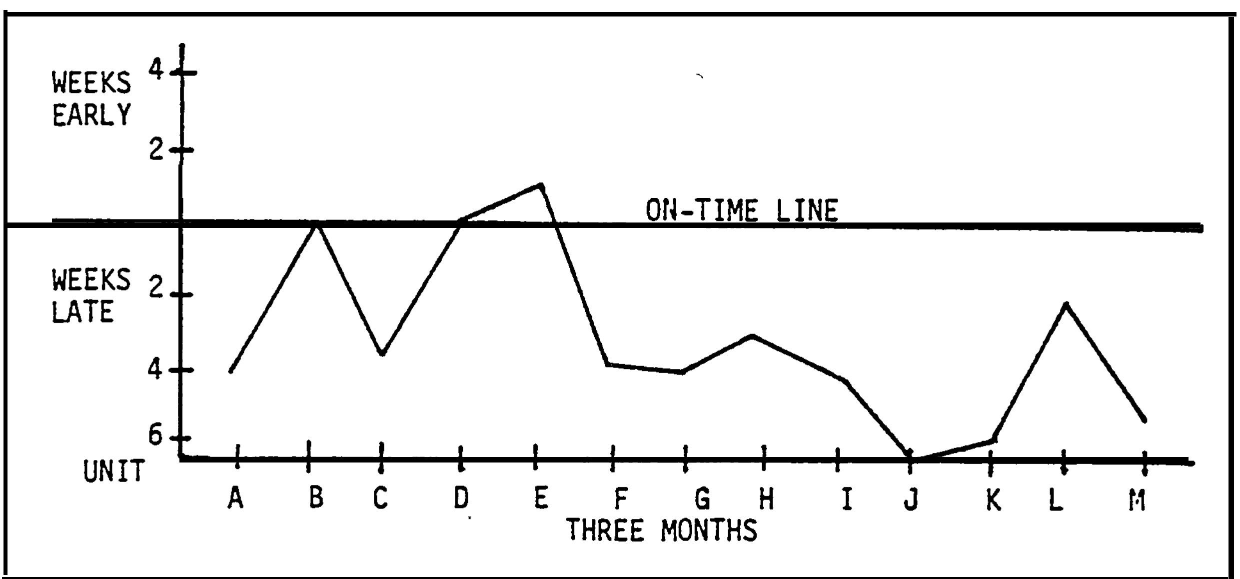

FIGURE III-7: SCHEDULE ADHERENCE PROBLEMS WITH HISTORICAL STANDARDS

Both early and late work packages have unfavorable impact on construction costs. Work that is completed early must be stored thereby incurring unnecessary material handling costs and inventory carrying charges. Work that is completed late usually entails expediting and overtime costs and has disruptive effects on assembly schedules.

Reducing variance of work package duration distributions (as in Figure III-8) will permit tighter scheduling of work, thereby reducing cost of early and late completions. This is one of the primary objectives in improving the accuracy and reliability of standards used in the planning and scheduling

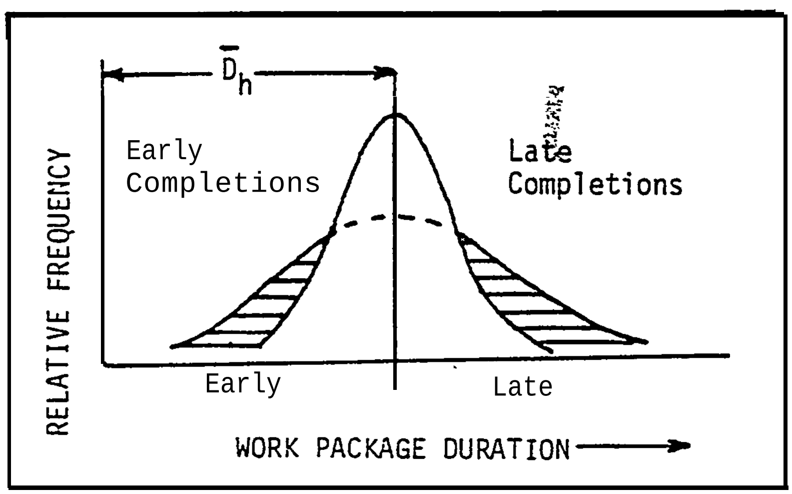

FIGURE 111-8: BENEFIT OF COMPRESSING DISPERSION OF WORK PACKAGE DURATION

process. With such improvements, improved production control becomes possible.

SECTION IV

IMPORTED STANDARDS

IV: IMPORTED STANDARDS

4.1 Preliminary Distinctions

Evaluation of Imported Standards and Engineered Standards in the steel fabrication plant was directed toward compressing the variance (Figure III-8) in both expenditure and duration about the planning means with the objective of reducing costs associated with early and late completions.

Planning and scheduling using either-Imported or Engineered Standards is a bottom-up process as distinguished from the top-down approach represented by the traditional method based on Historical Standards of the type illustrated above. In using either Imported or Engineered Standards, total work package budgets and planned durations are synthesized by combining process times and man/machine hour expenditures for each operation on each piece contained within a work package.

To show how this is done, it is convenient to introduce the concepts shown schematically in Figure IV-1 which portrays

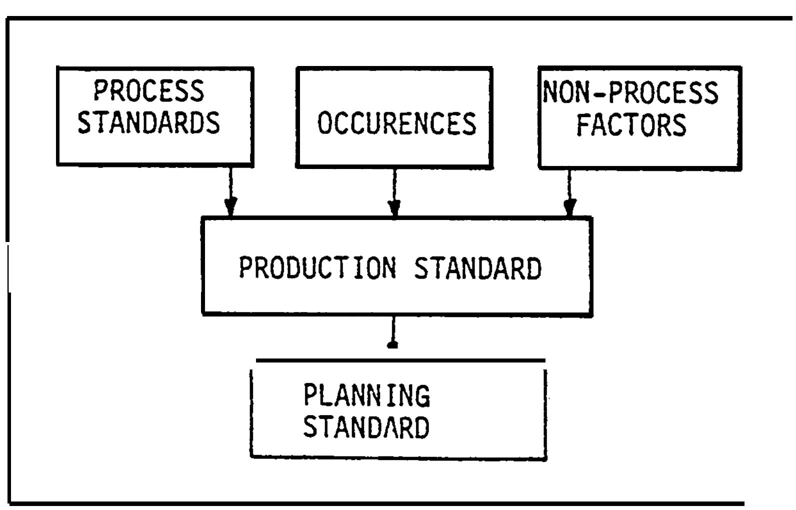

FIGURE IV-1: SYNTHESIS OF PRODUCTION AND PLANNING STANDARDS

the logic used in developing the standards that were evaluated in the planning and production control experiments.

a. <u>Process Standards</u> - These are standards applied to individual process operations such as welding, burnning, priming, etc., usually specified in terms of rates such as inches-per-minute, square feet-per-hour, etc., and exclude such factors as may change from location-to-location.

b. <u>Occurrence Allowances</u> - These are time increments which are included in a standard to account for unavoidable delays which interrupt the process operations; for example, changing the wire spool during flexcore welding operations, or moving safely aside because a crane load must be transported overhead.

c. <u>Non-Process Factors</u> - These are factors which impact total time and budget but are not contained in the process standard itself. Typical items in this category include allowances for machine operator fatigue, paid break or lunch, personal time, etc.

d. <u>Production Standard</u> - Whereas process standards apply to individual process steps, production standards apply to fabrication of complete pieces, e.g., structural shapes, webs, panels, etc. Production standards are developed by combining factors (a), (b), and (c) in the proper combination to develop total time and budget for the piece.

e. <u>Planning Standards</u>[1] - It was noted earlier that fabrication work packages may cover the fabrication of many separate pieces or small assemblies. The fabrication of each of these may be subjected to a different production standard as defined in (d) above. Establishing standard durations for complete work packages may be accomplished in one of two ways: first, by combining production standards for each of the many pieces/assemblies included in the work package; second, by developing approximate rules for simplifying production standards to determine work package budgets and durations while avoiding the very heavy planning effort implied by the first method. The approximate rules are referred to hereafter as "planning standards." Their derivation and use is discussed further in Section V and Appendix B.

Production standards are thus synthesized from process standards, occurrences and other non-process factors. Planning standards, in turn, are approximations to one or a group of production standards.

1. During the research and the earlier draft of this report, these standards were referred to as "Scheduling Standards." Since the name "Scheduling Standard" led to some confusion, it has been renamed "Planning Standard" which snore accurately reflects the basic concepts involved.

4.2 Imported Standards

The objective of the experiment with Imported Standards was to determine whether standards developed outside the shipyard could be used to improve fabrication plant performance. If so, a shipyard need not incur the cost of developing the standards themselves and could still reap the benefits of improved performance expected from the use of standards in the planning function.

An outside consulting firm was retained to assist in this phase of the experiment. This firm, which had provided consulting to both shipbuilders and to other manufacturing and construction companies, had ready access to production standards developed elsewhere. Since these were production standards, they included both process factors such as welding rates and non-process factors such as set-up times, personal times, fatigue allowances.

It was assumed prior to the experiment with Imported Standards that adaptation of the standards to the production environment of the steel fabrication plant could be accomplished by modifying the non-process factors in the standards. Accordingly, changes in factors such as these were evaluated:

- Material flow and handling facilities
- Manufacturing equipment
- Labor rules
- Dimensional tolerances
- Product design
- Quality requirements

The consultants used their judgement to determine the impact of these factors and modified the imported production standards accordingly.

In addition to the modification of standards to fit the circumstances of the steel fabrication plant, it was necessary to modify the planning and scheduling system to use the scheduling standards for welding, for fitting and for burning to determine the shop time required. In addition, the weekly workload for each craft was tabulated. Unit start dates were then determined so that the following criteria were met:

- Unit was completed on schedule.
- Tonnage goal was met.
- Craft workloads were uniform.

The amount of in-process inventory was allowed to fluctuate as required.

The actual schedule was compared to the planned schedule and schedule performance reported. The actual labor hours were compared to the budgeted labor hours. In this manner, the performance when using Historical Standards was compared to the performance when using Imported Standards and when using Engineered Standards.

4.3 Results Of Experiments With Imported Standards

Imported Standards were used to cover the production operations listed in Table IV-1 for which historical information was also available.

Type Of Process	Historical	Imported
Burn	Yes	Yes
Layout	Yes	Yes
Bending	Yes	No
Fabrication	Yes	Yes
Welding	Yes	Yes
Material Handling	Yes	No

TABLE IV-1: IMPORTED STANDARD USAGE

Table IV-2 is a typical example of the results of comparisons between use of Historical and Imported Standards at the production process level. The example in this case is for plate burning.

Type Of Standard	1/4″ Plate			3/4″ Plate		
	Budget	Actual	Perf	Budget	Actual	Perf
Historical	1.67	1.45	115%	1.67	2.1	79%
Imported	2.01	1.45	138%	3.11	2.1	150%

TABLE IV-2: COMPARISON OF HISTORICAL AND IMPORTED BURNING RATE STANDARDS

Note that here there is a greater difference between budgeted time and actual time for the Imported Standards then there is for the Historical Standards. These numbers are <u>averages</u> taken from several tests. Of greater interest, following the discussion in Section 3.3 and Figure III-8, is the variation in actual hours about the standard. As noted before, the less reliable the standard the less useful the standard becomes for planning and production control purposes.

Figure IV-2 is an example of the reliability of Imported Standards for an optically directed 1/10 scale burning machine.

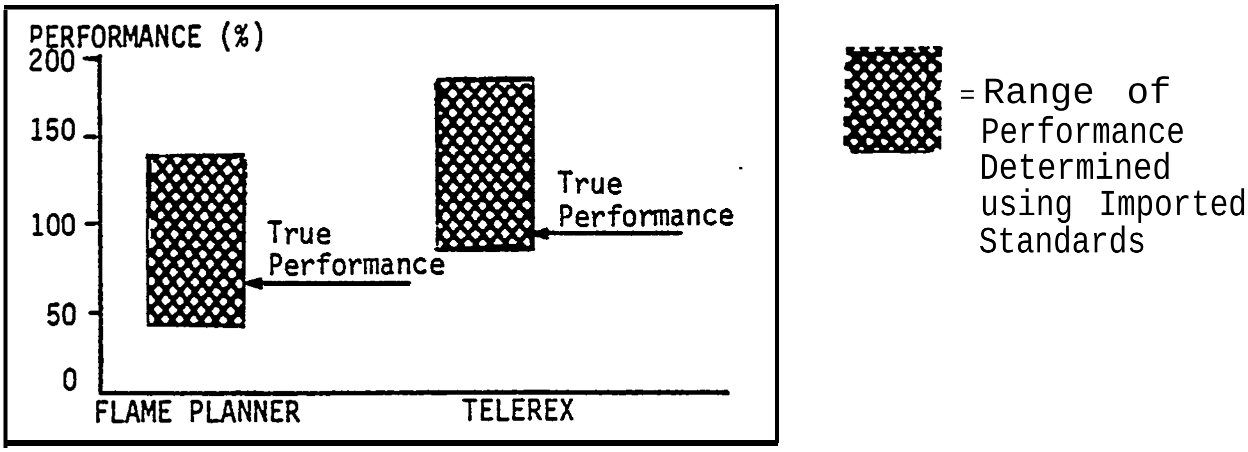

FIGURE IV-2 : VARIABILITY IN PERFORMANCE
REIATIVE TO IMPORTED STANDARDS

In these two distributions, the variable measured is performance- to-standard which equals the quotient of the standard hours divided by the actual hours, then multiplied by 100 to convert the ratio to a percentage.

4.4 Observations On The Use Of Imported Standards

The use of Imported Standards did, in fact, provide some improvement in steel fabrication plant throughput and schedule adherence.

However, one of the most important observations made during the conduct of these experiments was the need to obtain the confidence of first line supervisors and mechanics in the reliability of the standards used. A prerequisite to obtaining this confidence is consistency in the results. Early in the experiment results using Imported Standards were so inconsistent and erratic, as illustrated in Figure IV-2, that initial skepticism of plant personnel in the standard program was strongly reinforced. Confidence and support

of the project were not achieved until the Imported Standards had been replaced by Engineered Standards and the Engineered Standards had been successfully validated for an extended period of time. Full confidence and support of the work was finally obtained when the effectiveness of the engineered production standards had been demonstrated -- thereafter use of standards was enthusiastically supported by the majority of the supervisory force.

It was further observed that with additional effort the reliability of Imported Standards could be improved. However, the cost of doing so would be equivalent to the cost of developing a full set of Engineered Standards for the plant.

Finally a clear distinction should be drawn between &-porting standards from outside sources and transferring standards from one machine or process to an identical (or similar) machine or process. Process standards developed for one Telex machine are transferable to a similar Telex machine. However, production standards are not directly transferable from one type of machine to another. The standards that were imported do not address inter-machine transferrability requirements but rather only the general processes of welding, burning, etc. Importation of standards can be successfully accomplished if intermachine/process transferrability requirements are duly recognized.

As the result of these observations the Task 0-2 study team concluded that:

a. The bottom-up approach to developing production and planning standards from process standards

was significantly superior to the use of historical standards based on tonnage rules alone.

b. Process standards must be engineered within the using activity; or at the very least, applicability of standards developed outside an activity must be validated by physical measurement within the activity before their use as integral parts of the planning and scheduling process is justified.

c. Production standards must include non-process factors (Figure IV-1) if they are to become valid planning norms.

SECTION V

ENGINEERED STANDARDS

V. ENGINEERED STANDARDS

5.1 Developing Engineered Standards

To develop Engineered Standards for use in the planning and production control process, it was first necessary to establish process standards and allowances for non-process factors as defined in Section 4.1 and illustrated in Figure IV-I. Work content is usually determined in the planning process (e.g., feet of weld are calculated from drawing) and are used only in planning specific jobs. On the other hand, process standards are usually presented in the form of tables or graphs which specify process rates for various material conditions, as, for example, feet of weld for plates of different thickness and root openings.

Establishing an appropriate set of process standards (e.g., rate tables) is complicated by the fact that rates will vary depending on values of input parameters. Thus, welding rates will vary in accordance with input current; burning rates and edge quality will depend on torch tip size and fuel input rate, etc. However, “standard rates” or “optimum practice rates” are used in process tables.

To engineer the process standards two steps were necessary: first to collect rate data for a variety of different conditions; and second to select those conditions which resulted in optimum (or acceptable) process rates. Processes for which Engineered Standards were developed are listed in Table V-1.

Type Of Process	Type Of Standard		
	Historical	Imported	Engineered
Burn	Yes	Yes	Yes
Layout	Yes	Yes	Yes
Bending	Yes	No	No
Fabrication	Yes	Yes	Yes
Welding	Yes	Yes	Yes
Material Handling	Yes	No	No

TABLE V-1: PROCESSES FOR WHICH STANDARDS WERE APPLIED

An unexpected result of the experiments in the steel fabrication plant was that it was discovered that input conditions for many processes were far from optimum (e.g., welding currents were too low) so that respecifying process "methods" resulted in immediate productivity improvements. These are referred to as "methods improvements" and are not to be confused with productivity improvements from use of Engineered Standards in the planning and production control functions themselves. The Appendix contains samples of these various types of standards.

The remainder of Section V is organized as follows: Section 5.2 describes how Engineered Process Standards were developed and the immediate methods benefits obtained thereby. Section 5.3 describes results of using Engineered Standards in the planning process and the resulting impact on steel fabrication plant throughput and schedule adherence. Section 5.4 discusses the use of planning standards as approximations to the more accurate production standards.

5.2 Developing Engineered Process Standards

In developing Engineered Standards for production processes two steps are necessary. First, process rates must be

measured for various input conditions e.g. , weld deposition rate as a function of weld current. Second, on the basis of the rate measurements, the optimum rate must be selected considering such factors as quality, cost, etc. Input setting for the optimum rate then becomes the standard method and the associated process rate the standard rate which are used in synthesizing the production and planning standards. These two steps are covered in subsection 5.2.1. Subsection 5.2.2 discusses the benefits from improved process methods resulting from the application of process standards.

5.2.1 Establishing Process Rates

Accepted professional industrial engineering techniques were utilized to measure processing rates for these operations in the steel fabrication plant:

- Oxy-fuel gas cutting (machine and manual).
- Plate and shape layout.
- Part assembly.
- Welding.

The necessary support trades were included in the standards except for maintenance, grinding and some of the material handling functions. Lack of time prevented the latter from being included in the data base of process standards developed as the result of this experiment, but there is no question that the method used can be applied to all of these trades, and that the conclusions reached by the study will apply equally well to these service groups.

A. Burning Machines Rates

The first area that was selected for study was plate cutting on the Telerex Machine. It was necessary to determine the optimum torch travel speeds to be used. Initial data revealed that the cutting speeds being used were significantly below those recommended by the tip manufacturers for the plate thickness and bevels. It was therefore decided to experiment with cutting speeds to see if they could be optimized.

An experienced burning machine operator, who was also a part time supervisor, was assigned to this task. For several weeks he worked with an industrial engineer and they developed an optimum speed, tip size, fuel pressure and volume, oxygen volume and pressure setting for each thickness of plate, edge bevel and surface condition, (blasted, blasted and primed with paint, blasted" and primed with inorganic zinc primer). Torch travel speeds were increased until the quality of the burned edge was declared unacceptable, and then the speed was reduced so that a consistently acceptable edge was produced with no "flame outs" resulting from the speed. This speed was then the maximum operating speed. Standard times were set, however, using a number that was about 80% of the maximum operating speed to take into account atmospheric conditions, changes in gas conditions, and to set the level for a second class burner rather than the first class man who had run the tests. Results of this exercise are shown in Figure V-1.

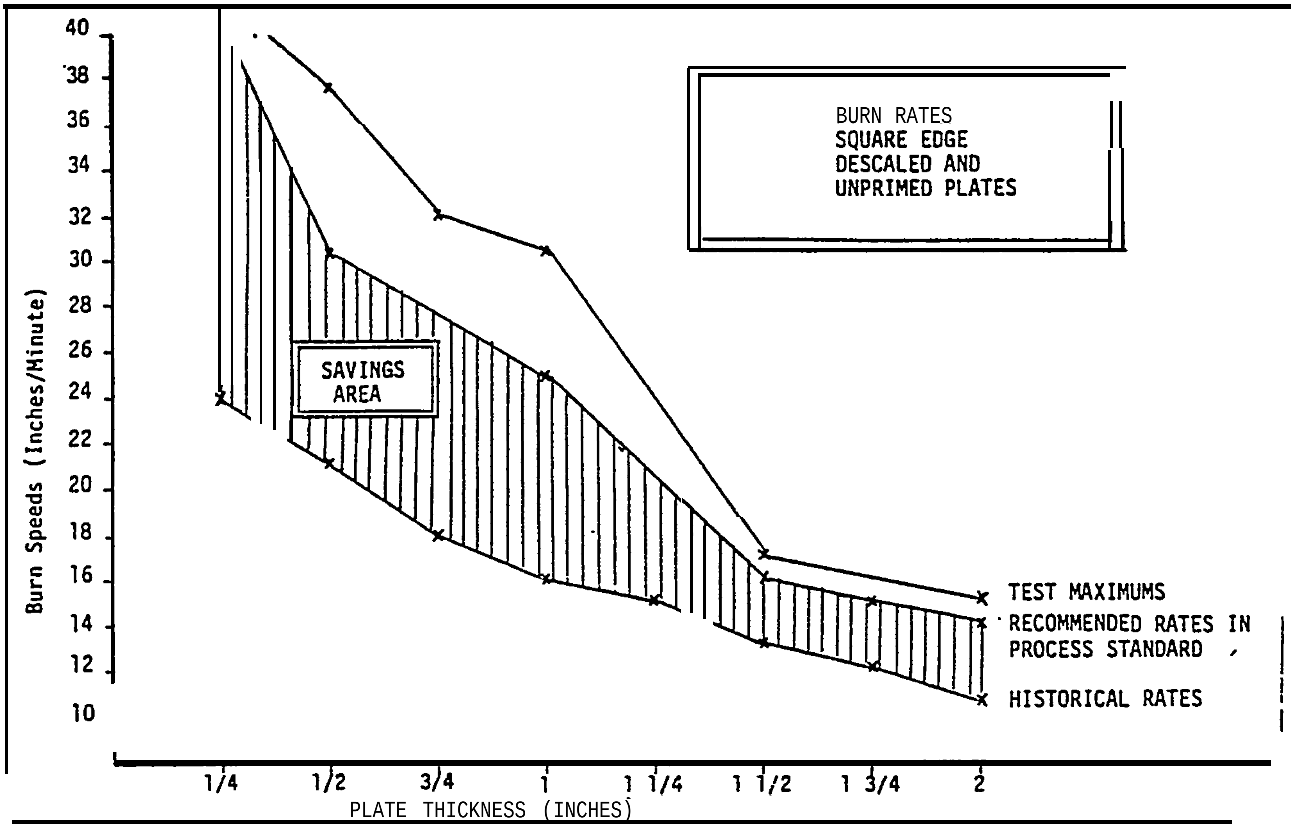

FIGURE V-1: BURNING SPEEDS AS A FUNCTION OF PIATE THICKNESS. HISTORICAL, STANDARD, AND TEST RESULTS ARE COMPARED.

In addition to establishing the optimum burning speeds, stop watch measurements were made of the other work that the operators had to do. For example, the load and unload cycles were measured. So were the times to replace tips and adjust torches. In addition to the times established by direct observation and stop watch timing, some moves were given standard times by using standard time data from commercial sources.

The miscellaneous work which had a low occurrence factor and was not individually reported as work accomplished, was handled in a different reamer. A calculation of the amount

of this low occurrence work was made for each operation. A standard time was estimated for that work, and the resultant extra hours which would have been “earned" were added as an extra percentage to the measured and reported earned hours.

Table V-2 is a comparison of burning rate performance using Engineered versus Historical and Imported Standards. Note that not only is performance closer to standard but also that Engineered Standards provide a much more accurate reflection of work content and thus more fairly reflect the operator’s effort -- a very important factor in establishing worker confidence in Engineered Standards.

TYPE OF STANDARD FOR BUDGET	1/4″ PLATE			3/4″ PLATE		
	BUDGET	ACTUAL	PERF	BUDGET	ACTUAL	PERF
HISTORICAL	1.67	1.45	115%	1.67	2.1	79%
IMPORTED	2.01	1.45	138%	3.11	2.1	150%
ENGINEERED	1.32	1.45	90%	1.91	2.1	90%

TABLE V-2 : COMPARISONS OF REPORTED PERFORMANCE US I USING HISTORICAL, IMPORTED, AND ENGINEERED BURNING RATE STANDARDS

The use of Engineered Plate Burning Standards resulted in an actual productivity improvement of over 30% in burning rates.

B. Welding Rates

The same approach was used in establishing standard welding times. The welding engineer assigned to the task team reported that the deposition rates given in the literature were very erratic and the inconsistency from one source to another would mean that the 0-2 team would have to generate their own data.

Consequently a procedure similar to that for establishing burning rates was followed in establishing welding rates. A welder was assigned to the project teem. Process parameters were varied until the best results were produced. The welding process was timed. All welds were checked for quality. All electrodes, processes, Plate thickness, edge preparations, primers, etc., that are normally used at BIW were tested. The resulting data was used to determine time-per-foot-of-weld. In addition, the cost of making welds was calculated (labor and material, rework, etc.). Planning then began specifying the process with the least total cost to be used when subsequently developing the budgets for work packages.

Figure V-2 is illustrative of the way conditions were varied to determine standard conditions. In this example, welding cost (labor plus welding material) was determined for various root openings for three welding orientations -- horizontal, overhead and vertical. For the horizontal case, cost of welding plates with root opernings of one-quarter of an inch is four times higher than welding cost for root openings of one-eighth of an inch. A root opening of 1/8″ was determined to be standard for setting both fitting and welding budgets.

5.2.2 Benefits From Development Of Process Standards

A process standard is a rule which established standard process rates under specified standard process conditions. Although it was not the intent of the research to measure improvements at the process standard level since process standards were merely the vehicle for synthesizing the production

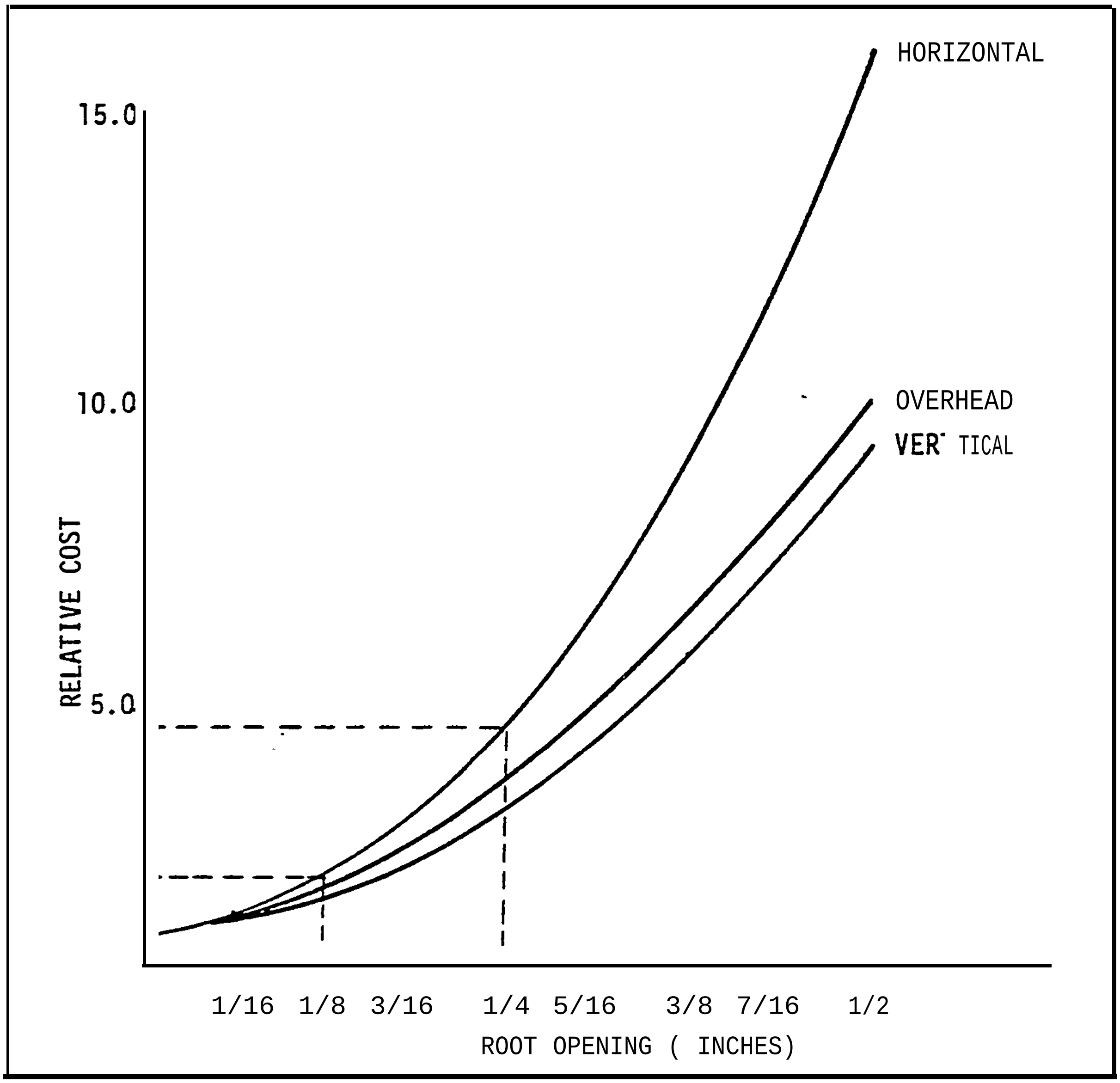

FIGURE V-2 : THE LABOR AND MATERIAL COST FOR DIFFERENT ROOT OPENINGS

and planning standards on which the research was focused, significant improvements in productivity did in fact emerge as the result of developing process standards.

For example, development of welding standards produced results (Figure V-3) leading to an overall average reduction in welding times of 10% and an expected annual savings of $52,000 per year.

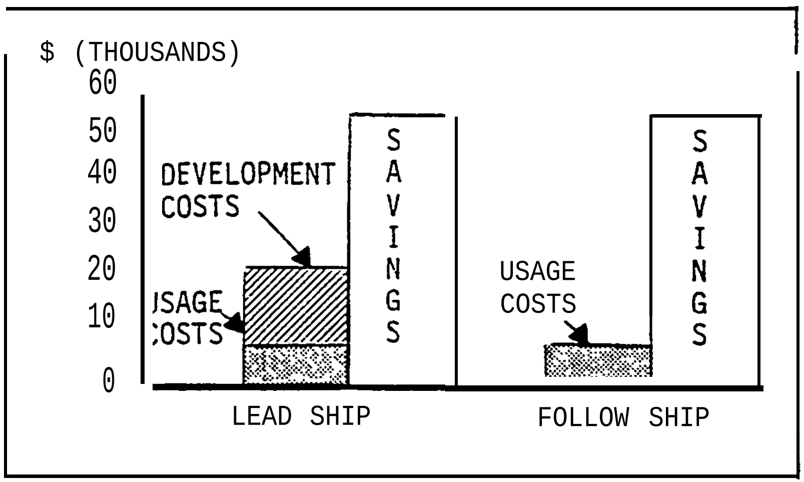

FIGURE V-3: SAVINGS EXPERIENCED FROM WELDING PROCESS STANDARDS

As another typical example, plate burning standards resulted in actual average productivity improvement of over 30% in burning rates.

Figure v-2, which shows welding time as a function of root opening and material orientation, is still another graphic example of the sensitivity of process time (and therefore cost) to process conditions. This type of graph is a basic input to production standard, since before the optimum spacing between pieces can be specified, the cost of burning, fitting and tacking which is highly sensitive to spacing, must also be considered in order to obtain the best combination for all the affected trades in establishing the production standard.

Engineered Standards were applied to the fabrication operations for the final set of units for the third hull and the first set of units for the fourth hull. Performance-to standard measurements were averaged for fitting and welding operations for a representative sample of the same units on each of the four hulls. Results of the comparisons are shown in Figures V-4 and V-5 respectively. Averages for the first two hulls represent performance based on traditional tonnage rules; averages for the last two hulls represent performance after Engineered Standards had been applied. For fitting operations, improvements of about 20% were obtained; for welding, over 30%.

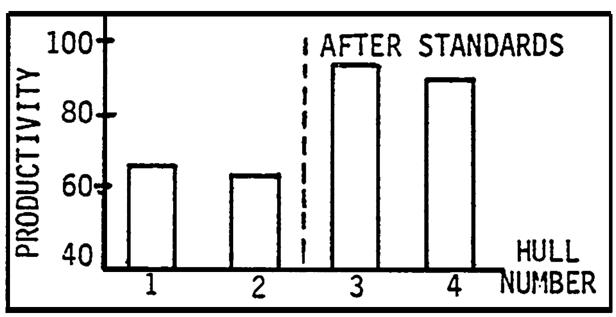

FIGURE V-4 : CHANGE IN PRODUCTIVITY OF FABRICATION FITTING FOR SEVEN UNITS FOR EACH HULL

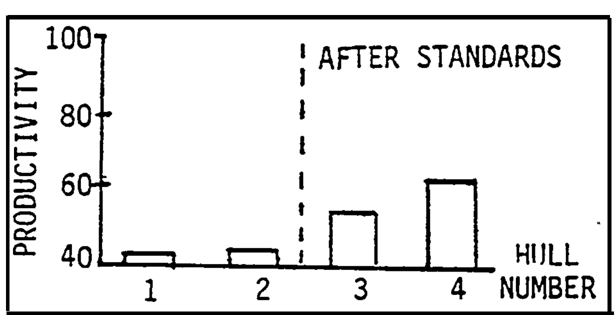

FIGURE V-5: CHANGE IN PRODUCTIVITY OF FABRICATION WELDING FOR SEVEN UNTIS FOR EACH HULL

5.3 Use Of Engineered Standards In Planning

5.3.1 Production Standards And The Planning Process

It will be recalled (Section 4.1) that whereas process standards apply to single operations, production standards cover all steps for a complete job, as for example, the burning of a plate which includes set-up, load, burning, unload, scrap clean-up plus allowances for operator fatigue, machine maintenance, etc.

A detailed production standard was written for each process (see Appendix B for details)whereby times could be calculated for each task based upon the work to be performed. The times in the standards were established either through stop watch time study or by the use of standard data which was established through stop watch study. The production standards treat separately all variables that have more than a 3% influence on the process time.

Each task was analyzed in detail to insure that each necessary step was covered. The content then became a written document for use in future methods analysis. It was at this time that operation parameters were evaluated and the best parameter values specified as standards.

It will be recalled that a fabrication work package covers all work required to fabricate all pieces for a single 200 ton (or less) erection unit. Establishing the standard hours and the standard time for work package involves the process shown in Figure v-6. Also see Appendix B for further details about the development of standards.

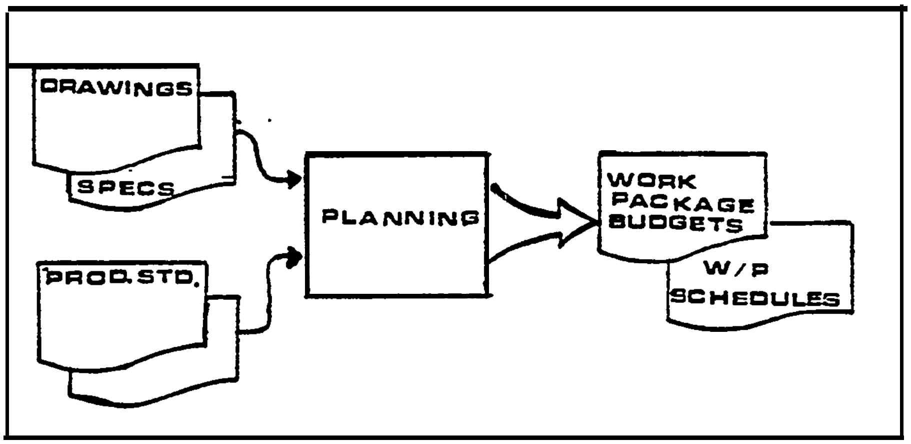

FIGURE V-6 : APPLYING STANDARDS IN THE PLANNING PROCESS

The drawings and specifications provide the basic design information for planning the job and are the source of work content information (e.g., feet of weld). The standards are used to determine the time requirements for labor and facilities which, in turn, are the basic inputs used for loading and scheduling work on the steel fabrication plant.

The last erection units in the third and the first erection units on the fourth ship in a contract for four identical 20,000 DWT commercial ships were planned and scheduled by this method. Plant performance on this sample was then compared against performance measured on the first two ships in the series.

5.3.2 Experimental Results

Planning fabrication work packages following the procedure outlined above views the steel fabrication plant as a single production unit for which two measures of performance can be applied:

- Schedule Adherence
- Productivity

Figures V-7 and V-8 show the performance improvements resulting from the application of Engineered Standards to the fabrication work packages. Improvements in schedule adherence represented in Figure V-7 reflect a reduction in average time late of from four weeks to zero weeks, and maximum time late of from seven weeks to two weeks.

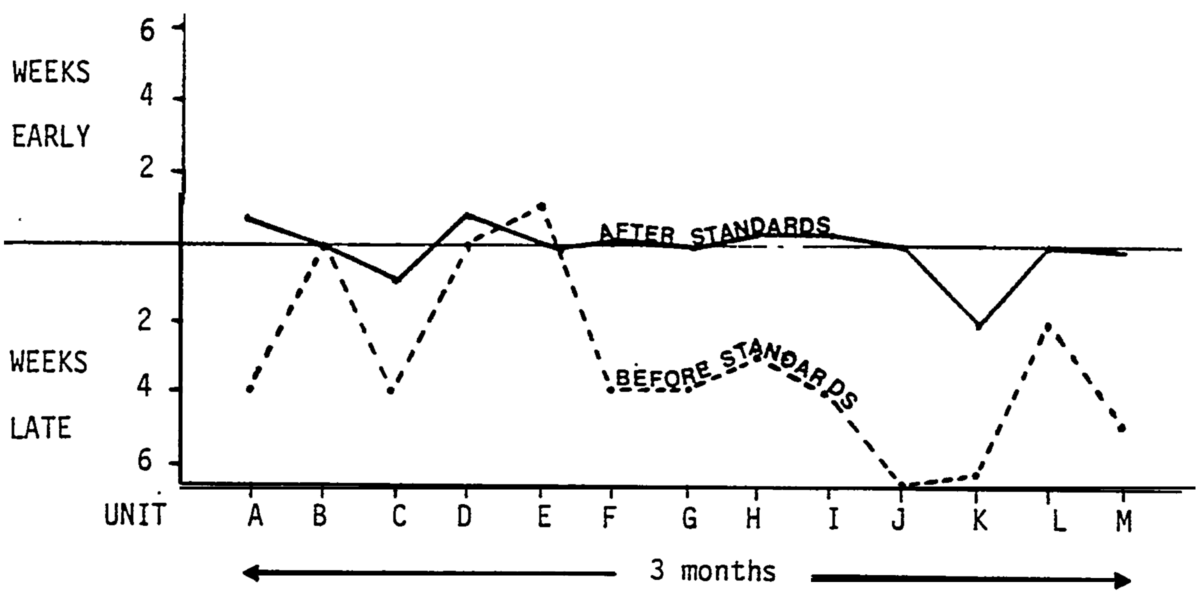

FIGURE V-7: IMPACT OF STANDARDS ON SCHEDULE COMPLIANCE

Productivity improvements (Figure V-8) measured in man-hours per ton are equally dramatic, reflecting as they do about a 20% increase in productivity during the period of the experiment.

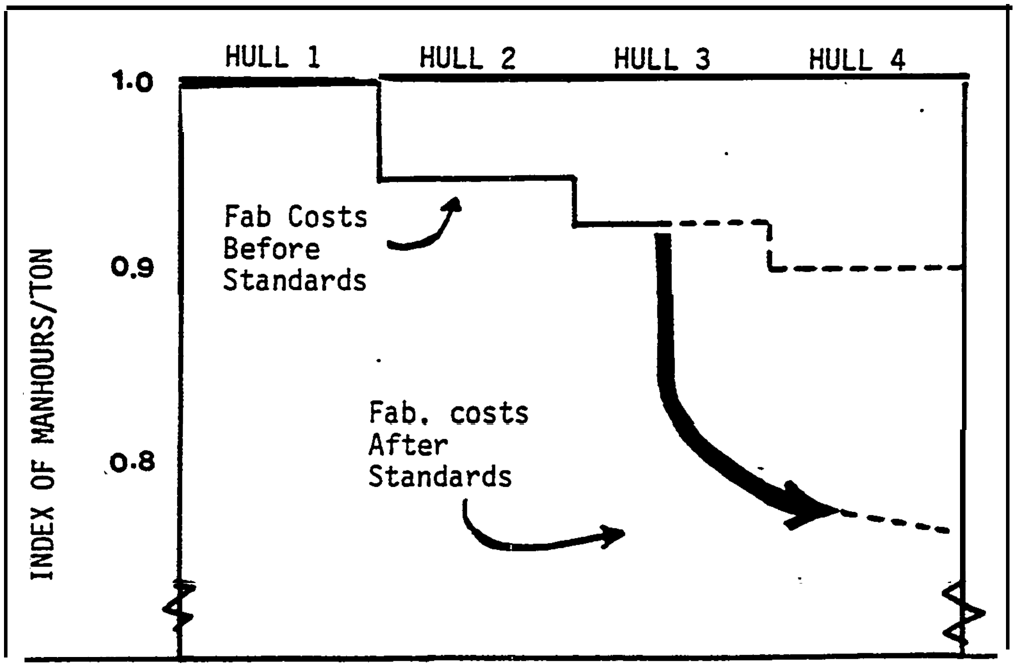

FIGURE V-8: PROJECTED PRODUCTIVITY IMPACT

Eighty-five percent of the steel fabrication man-hours in the plant were subjected to standards during the experimental period; if all operations had been covered, improvements would have been even greater.

It is also of interest to note the benefit-s that engineered production standards have on smoothing workload. Loading the fabrication plant on the basis of tonnage output needed to satisfy erection schedules resulted in extremely erratic output compared to the planned output schedule (Figure V-9).

The peaks in planned load were imposed by demands of the erection schedule; overtime was scheduled to work them off. Excursions in actual output were the direct result of differing work content and material characteristics of the unit fabrication work packages. When the actual work contents of units scheduled through the steel fabrication plant during the

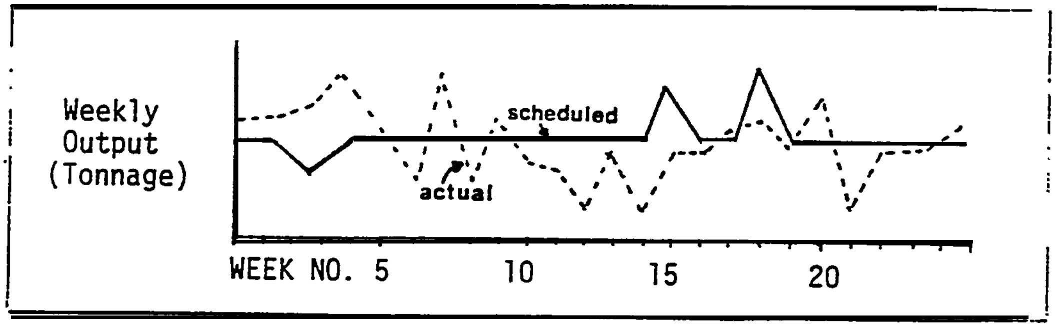

FIGURE V-9: ACTUAL VS. SCHEDULED OUTPUT FROM TONNAGE LOADING RULES

experiment was measured by Engineered Standards, the man hours varied from one week to the next by as much as 5,400 man hours or 135 people. This created a combination of two situations:

a. The Master Schedule was ignored in favor of producing the goal tonnage.

b. The Master Schedule was followed as well as possible with massive amounts of overtime necessary.

What in fact resulted was that neither intention was successfully carried out. The inadequacy of tonnage rules to provide accurate long range workload forecasts made it impossible to adjust the work force or fill in with over-time to the degree needed.

Work was scheduled only to a completion date; there were no intermediate or start dates supplied. Production Supervision had to work backward from the completion date to establish start dates. Job scope was estimated from past experience on similar work. The short workload visibility prevented any long range planning or level loading of the

production people.

The level loading concept was introduced by the 0-2 team. Level loading consisted of determining work content visibility three months ahead, loading the plant to support the Master Schedule, and keeping the manning at a constant level. This was done by advancing start dates on some units to fill in slack periods and ease heavy demand periods.

The effect of level loading the plant based on work content as determined from Engineered Standards was quite impressive. On-time completions of units improved to the point where the schedule was actually adhered to. As more on-time completions were accomplished, confidence in the schedule and the scheduling method grew. This in turn caused production supervision to strive all the harder to remain on schedule. During the 0-2 task, the overtime expenditures decreased as emphasis was shifted from tonnage output to scheduled output.

5.4 Cost-Benefit Analysis Of Engineered Standards

5.4.1 Cost Of Developing Standards

Three basic cost factors are associated with incorporating standards into planning and production control. The first is the development of the engineered process standards themselves, which are the basic elements out of which the production and planning standards are synthesized (Figure IV-I). Costs associated with this step include the tradesmen's time required to accomplish the various processes under a variety of different conditions as well as industrial engineering time required to observe the operations and collect the desired data.

Cost of developing process standards is a <u>one-time cost</u> for a shipyard since the data produced can be used on all contracts for which the operations covered by the standards are required. Cost of the process standard development should be prorated over all contracts. In the Task 0-2 experiments, cost of developing process standards for 85% of the operations in the steel fabrication plant was 4,800 man-hours (approximately $30,000).

During the experiment with Imported Standards it was observed that although some were applicable with minimal modification, most were not. Accordingly, all process standards developed outside a shipyard would require thorough validation within the shipyard before they could be used with confidence in the planning and production control function. Since validation costs were roughly equivalent to costs of developing process standards from scratch, and the Imported Standards were still not as effective as Engineered Standards, it was concluded that engineering the standards on-site was the most cost effective approach.

5.4.2 Cost Of Applying Standards

Once tables of process rates, allowances, etc. (that is, process and production standards) have been developed, they must be applied to develop budgets for trades and machines and time estimates for each of the work packages in a construction project -- following the process shown schematically in Figure V-6 (and described in detail in Appendix B).

The cost of using or applying the standards is significant. In the Task 0-2 experiment, the marginal increase

in planning cost incurred from use of the standards, above and beyond normal planning costs using tonnage rules, was 3,300 man hours ($22,000) for steel fabrication work packages. Note that this is a one-time cost for a contract. If the contract covers more than one ship, then the cost should be pro-rated over the number of hulls in the contract.

In using production standards for planning and scheduling, it was observed that some standards were more difficult and took more planner hours to apply than others. The study team also observed that the higher the application costs the less the gain in net cot savings from increased productivity of the work packages planned, as illustrated graphically in Figure V-10.

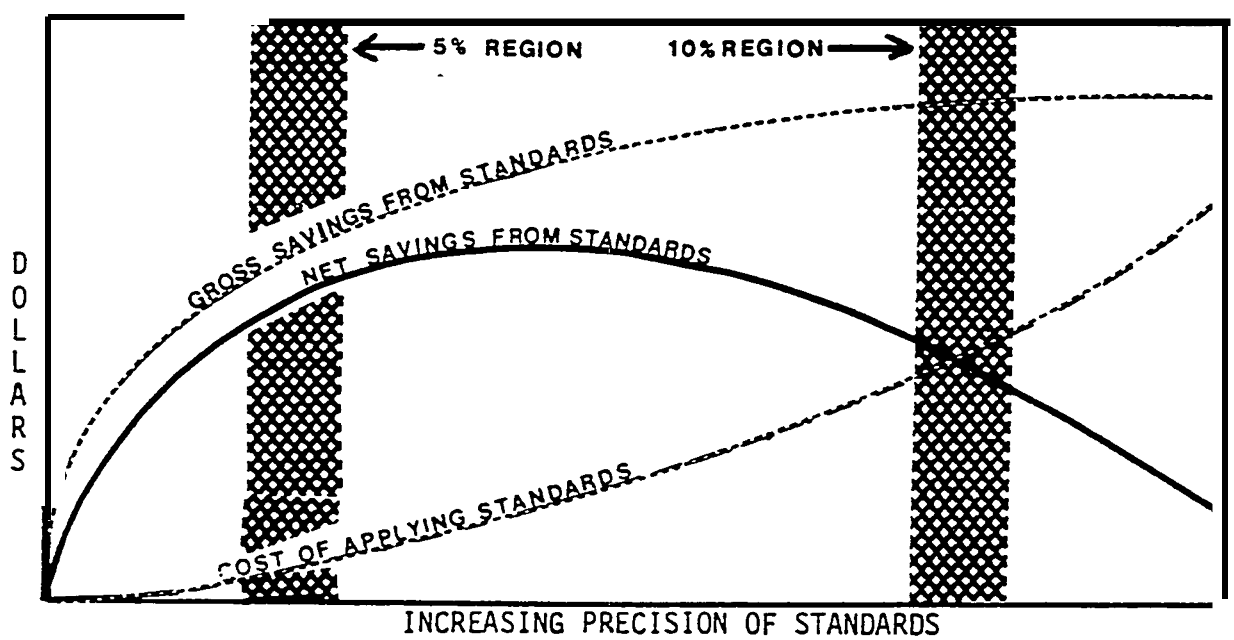

FIGURE V-10 : ECONOMICS OF STANDARDS APPLICATION

It was concluded, as a general rule of thumb, that if the hours required to apply the standards exceeded 10% of the standard hours for the work package, then the use of standards had passed the point of diminishing return. Beyond that point the cost would most likely exceed the return. On the other hand if the cost of applying the standard was 5% or less, then use of the standard was clearly profitable. When applications costs lay in the 5% to 10% range, value was ambiguous.

This conclusion does not imply that work packages for which applications costs were greater than 10% should not be subjected to standards, but rather that the standards were too precise and difficult to apply, and that substitution of less complex standards should be investigated. For this reason planning standards were developed to reduce application costs to an acceptable level: ideally less than 5% of the standard hours. The guidelines established by the 0-2 team were as follows:

1. A standard that required more than 10% of the standard hours to apply was considered unacceptable for planning purposes.

2. A standard that required between 5% and 10% of the standard hours to apply was considered marginally acceptable for planning purposes. An effort was made to develop a more streamlined standard; however, if none could be developed the production standard was used for planning.

3. A standard that required less than 5% of the standard hours to apply was considered acceptable for Planning Purposes.

An analysis of the production standards was therefore conducted to identify those for which preparing the simpler planning standards was desirable. Items that accounted for small percentages of the standard hours were grouped or approximated as a percentage of the total without much loss in overall accuracy. Items that tended to increase application time were found to be: limited access to necessary information, the necessity to gather information from multiple sources, complexity of calculations, etc. Conversely, items that tended to reduce application time were found to be: a single source for necessary information, use of simplified sketches that pertained only to the operation being measured, use of fully dimensioned sketches and templates, use of approximations that lead to “standard times” for typical pieces, and easy calculations in the application process.

Other simplifications included grouping of process factors that made only small percentage contributions to job budgets. For example, variables with over 10% contribution to job duration were treated separately while those with less than 10% influence were grouped wherever possible. During the grouping, care was exercised to insure that the accuracy of the resultant planning standard remained within 7% of the production standard.

Seven welding production standards were consolidated into one scheduling standard with tables and allowances combined and simplified where possible to yield a best method planning

standard. Some approximations were made for shift start-up, job set-ups and material handling delays. As a further aid to reducing application times, several application tables were. developed to cover welding for the contract in-house during the O-2 task. These tables took typical pieces of structure such as innerbottom floors or longitudinal girders and assigned welding times including all appropriate allowances based on the number of stiffeners and length, type and size. A check was made as to the accuracy of these tables by applying times to erection units using separately the tables-and the planning standards. Deviations in the unit totals from the use of the tables amounted to 1%-2% because of the slight differences between the actual subassembly and the typical subassembly. The application costs of the welding production standards were measured at about 8% of the standard hours; use of the tables reduced this cost to less than 6% of the standard hours. This 25% reduction in costs resulted in less than a 2% loss in accuracy in the scheduling process.

For the fitting and tacking process only a production standard was developed. Application of the production standard required only 5% of the standard developed man-hours, so it was considered acceptable for use as a planning standard. No effort was made to further streamline the application process during the 0-2 task.

For the shape layout process, the production standard required about 12% of the standard hours to apply. This was considered unacceptable for use as a scheduling standard, so one was developed that required only 1-2% of the standard hours to apply.

Table V-3 shows the percentage ratio of the planning hours needed to develop fabrication budgets to the standard budget hours developed.

FUNCTION	TYPE OF STANDARD		ERROR INTRODUCED
	PRODUCTION	PLANNING	
WELDING	8%	5-6%	1-2%
BURNING	7%	4%	1-2%
FIT UP AND TACK	5%	N.D.*	N.D.*
SHAPE LAYOUT	12%	1-2%	1-2%

* N.D. = Not Developed

TABLE V-3 : COST TO APPLY PRODUCTION AND PLANNING STANDARDS TO FABRICATION SHOP FUNCTIONS

5.4.3 Cost Of Collecting Expediture And Performance Data

Effective use of standards in controlling production operations requires a feedback data collection system for measuring actual expenditures and progress against budget and schedule. Since finer grain feedback data is required when engineered standards are used in place of traditional data collection at the work package level, additional costs are incurred for the data collection function. During the experimental period, additional data collection costs approximated 1% of the value of the fabrication costs. Dollar value of data collection costs per hull was therefore estimated to be about $11,000. Additional data collection costs required by the use of standards will be recurring costs for each hull, unlike standard development and application costs which are one-time costs for a shipyard and for a contract, respectively.

5.4.4 Cost-Payback Comparison

The experiment was conducted on a representative sample of fabrication work packages taken from the last two ships in the four ship construction contract. Extrapolating savings measured from the sample to estimate full savings for the last two hulls yields the projected savings shown in Table V-4.

COST ELEMENT	HULL 1	HULL 2	HULL 3	HULL 4
1. Standards Development	--	--	$ 30	- -
2. Standards Application	--	--	22	- -
3. Performance Data Collection	--	--	11	$ 11
4. Cost Of Standards	--	--	$ 63	$ 11
5. Fab Costs W/O Standards	$1,300	$1,210	$1,160	$1,120
6. Projected Fab Costs W/ Standards	1,300	1,210	1,010	840
7. Projected Cost W/Stds. (Including Cost Of Standards)	1,300	1,210	1,073	851
PROJECTED NET SAVINGS	-0-	-0-	$ 87	$ 269

TABLE V-4: CALCULATED PAYBACK FROM USE OF ENGINEERED STANDARDS IN STEEL FABRICATION OPERATIONS (Dollars In Thousands)

Lines 1, 2, 3 and 4 cover the costs of standard development and application discussed above. Note that full cost of standards development and application has been assigned to Hull No. 3, when realistically it should be prorated *as* suggested in subsections 5.4.1 and 5.4.2.

Line 5 represents total fabrication costs of all four hulls with learning effects applied to the follow-on hulls but without the benefit of standards. Line 6 contains costs

of fabrication operations for Hulls 3 and 4 reflecting savings projected from use of standards. Line 7 is the projected fabrication costs of Hulls 3 and 4 including the cost of standards from Line 4. The bottom line in the table is the net savings from the use of standards. The full cost of developing and applying the standards is fully recovered on the first hull (Hull 3) to which they are applied and still standards yield an 8% “profit.” The “profit” on Hull 4 is about 25%.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

VI. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

On the basis of the shipyard survey, the literature search, and the experimentation with the use of Engineered Standards in the planning and production control of steel fabrication operations in the construction of two in a series of four 20,000 DWT cargo ships, the Task 0-2 study team con-eluded the following:

1. Productivity Improvement Potential - The use of standards in production planning and control can offer a reduction in the cost of steel fabrication operations of 20-30% over comparable operations planned and controlled using traditional tonnage rules. These cost reduction opportunities divide into two categories.

   Methods Improvements - Improvements in productivity due to improving the production processes themselves. A cost reduction of 10-15% of labor costs is easily obtainable.

   Planned Scheduling Improvements - Improvements due to more efficient flow and performance of work. An additional factor of 10-15% above process improvement should result from this factor. The total 20-30% overall improvement is the sum of methods and planned scheduling improvements.

2. <u>Improved Schedule Adherence</u> - Improvements in schedule adherence following the imposition of standards are dramatic. Use of standards instead of tonnage rules provides a much more accurate method for estimating fabrication plant capacity and provides much smoother plant loads. The average work package schedule late delinquency was reduced from an average of over three weeks late to zero weeks late. The maximum lateness was reduced from eight weeks to two weeks.

3. <u>cost</u> - The cost of developing and using standards can be recovered very quickly. These costs are divided into three categories:

   <u>Cost To Develop Process Standards</u> - The cost of developing process standards is a one-time cost for a shipyard. These standards are changed only when machines or processes are changed. For 85% coverage of all fabrication operations in the steel fabrication plant, cost of establishing process standards was 4,800 man-hours.

   <u>Cost To Apply Production/Scheduling Standards</u> - The cost of setting labor and machine budgets for steel fabrication work packages was 3,300 man-hours. As a general rule of thumb, cost per contract should not exceed 5% of fabrication costs for the first hull in a contract and should be virtually zero for follow hulls.

Cost Of Data Collection - Use of standards for Production Control requires collection of additional data above and beyond that required using traditional tonnage rules. Estimated cost of collecting this data is about 1% of total fabrication costs. This is a recurring cost on both lead and each follow hull.

4. Payback - The payback from use of standards for planning and production control is such that savings in increased productivity on a single hull is more than adequate to recover standards development and applications costs and still yield a net reduction of 5-10% in fabrication costs. Thereafter, cost reduction should equal 20-30% of fabrication costs.

5. Labor And Management Views Of Standards - The Task 0-2 study team concluded that positive attitudes and full cooperation from labor and management can be obtained for the use of standards if proper groundwork is laid. If the standards program is properly designed and applied, both labor and management can benefit. Benefits to labor are increased output frequently with less effort, full credit for work accomplished, and adequate provision for such factors as fatigue, personal time, and safety. Management benefitted from much better workload forecasting and work-in-process controls. If proper groundwork is not laid, if expectations are not clearly identified, and if cooperation of labor is not enlisted before a standards program is

instituted, then resistance from labor can jeopardize the program. Suggestions for proper indoctrination of management and labor are included in Appendix B.

6. Overall Management Improvements - The Study Team was unanimous in its belief that using the basic concepts and techniques of planning and control evaluated in this study throughout the management structure can make dramatic improvement in total shipyard performance and reduce or eliminate many of the chronic problems faced by shipyard management.

6.2 Recommendations

Section V presented the basic findings of the research portion of the Task 0-2 study. These findings plus other observations made throughout the study suggest a number of additional activities which the study team believes should be pursued to round out the research and to present results to the widest possible audience within the shipbuilding industry. Suggested further tasks fall within these three broad areas and are so grouped in the sections which follow:

- Validation of additional areas of benefit.
- Coummnication of results.
- Development of production oriented work breakdown structure.

These recommendations might form the nucleus of the proposed BIW Phase 2 Program.

6.2.1 Validation Of Additional Areas Of Benefit

The experimental work performed in the steel fabrication facility demonstrated conclusively that very significant savings are possible by improvements in the planning and control process. Task 0-2 Study Team is convinced of the validity of the conclusions and of the applicability of the technique to all of the shipbuilding functions. However, additional validation should be carried out to determine the actual cost and savings which would accrue from the use of Engineered Standards and tightened production control in such areas as:

- Panel and unit assembly.
- Unit erection.
- Pre-outfit and outfit.

Although the results are not encompassed within the scope of this report, the production standards have been set for the Panel and Unit Assembly operations at BIW. These standards can be used for budgeting, scheduling, and performance measurement. Planning standards should be developed and tested for all three functions listed above. The resulting benefits should be compared with the costs incurred, and this analysis should be published in a subsequent report to the shipbuilding industry.

Additional uses of engineered standards (see also Appendix A), include:

- Standard part costs.
- Cost estimating.

Standard part costs should be developed and used for two purposes. First, ship part designers should be taught how to select the parts used to solve a design need from a family of parts which are within design and specification constraints. Labor and material costs should both be included in the standard parts costs.

Cost estimating with standard part costs should be tested. A preliminary attempt to develop ship costs for bidding purposes was not successful because of the lack of a defined ship at the time of bid preparation. The European and Japanese marketing philosophy provides for much more detailing of ship parts before the preparation of the bid cost package. Mr. MacMillan [1] discusses this problem in his report on the Improved Design Process.

Tests of standards for estimating cost of design changes might prove more successful when the design is in a more complete state of development so that comparison of alternatives can be made against known objectives.

6.2.2 Communication Of Results

One of the great barriers to the implementation of cost reduction ideas developed under the MarAd Ship Producibility Program has been a misunderstanding of standards and their benefits. More complete understanding would promote greater

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1 MacMillan, Douglas C., "Improved Design Process," report prepared for the Ship Producibility Program under the National Shipbuilding Research Program, 1977 -- available from Bath Iron Works Corporation.

acceptance. Hence, this recommendation is directed at creating understanding among top shipyard decision makers about the potential cost reduction benefits that Improved Production Control would produce for them.

This technical report and its ancilliary Executive Summary should be given wide shipyard circulation. However, past experience has proved that this approach does not produce action decisions. Consequently, a shipyard visit should be made with an illustrative talk to supplement the published material. A summary presentation should be made to top management. A more detailed presentation should be made to planning and production control personnel and interested production and design personnel.

A Production Control Handbook' should also be prepared. This is the most important follow-on recommendation because it has been demonstrated that such a handbook is an absolute necessity if information is to be put in the hands of the user. This Handbook of Shipbuilding Planning and Production Control should be a practical textbook with "How To" answers. To date no adequate text exists in the area of planning and production control. Although some books have been authored, none of them address shipyard operations and very few of them are of the "Handbook for Users" type. Such a handbook should be <u>the</u> top priority item in the follow-on work.

6.2.3 Development Of-Production Oriented Work Breakdown Structure

One of the unsolved problem areas in "production control is the work breakdown structure. Although this problem is

outside the scope of Task 0-2 or the BIW follow-on program, it is certainly within the purview of this report to recommend that a production oriented work breakdown structure be developed under the guidance of SNAME Panel SP-2. Such a work breakdown structure would simplify budgeting, work packaging and cost collection for production control.

APPENDIX A

ADDITIONAL USES OF GENERATED DATA

APPENDIX A

OTHER USES OF ENGINEERED STANDARDS

1. Standards Fill A Need For Non-Historical Cost Data

After the Engineered Scheduling Standards were made available to BIW Planning personnel, requests came in from other shipyard departments for similar data to assist them in performing their work. The first requests were from the people who develop the bid costs for industrial work performed at the shipyard. They were preparing a cost estimate for work which management was very anxious to obtain. Due to the desirability of the work it was anticipated that the bidding would be most competitive. Consequently, it was important that the bid costs be prepared accurately. The estimators recognized that their historical data was not directly applicable because of some unique features of the work. Consequently, the estimators requested the assistance of the 0-2 Data Bank of Standard Times. Because their engineered standards covered basic process times, the 0-2 team was able to use the data directly to provide cost figures to the estimators.

The bidding on this task was successful and the cost estimating people now regualrly use Engineered Standards in determining costs.

This experience led to the question of how many other services could be provided by standard data. The additional uses of standard cost data beyond the obvious uses in Production Control are discussed below.

2. Standards Help Management Control Expenditures

The first group of uses involves using standards to determine reasonable costs under present circumstances and comparing these with the actual costs. Historical data can only say what has happened. They do not tell you whether the cost is too high, or whether it is reasonable. Standards permit the scientific manager to compare standard costs with actual costs and then to devote his effort towards cost reduction in the areas of greatest potential savings.

Quite obviously then, knowing costs as they ought to be and costs as they actually are leads directly to performance measurement in a rational manner. Measurement can be applied to any expenditure in a business if the actual cost can be assessed. Some suggested typical uses follow. Creative management will no doubt find additional ones.

2.1 Management By Objectives

The use of standards in a program offers top management an opportunity to manage by objectives, that is, to quantatively measure the achievements toward stated goals. Similarly, the person striving to achieve the objectives and thereby achieve good performance under the MBO program significantly benefits from the objective measurement. He knows ahead of time what the gauge is and the results are clear to him and to top management.

2.2 Piece Rate Or Incentive Pay Systems

This is especially useful when the existing rates have been used for a long time. Engineered Standards reveal whether

the original numbers were established in a systematic, rational and scientific manner and whether the required updating for methods change has been performed.

2.3 Work Performance Measurement

Even when dealing with the non-incentive paid workers, the use of engineered standards for work performance measurement gives very significant reduction in labor costs through performance improvement. Basic metal working industries have experienced productivity gains for measurement alone on the order of 15% to 25%.

2.4 Supervisory Performance Measurement

With a system of standards, performance evaluation can be based on that portion of the task which is under the control of each supervisor. There is no more need for the “shot gun” approach to accountability. The norm for performance can now be applied to the controlling supervisor.

2.5 Control Of Work Methods

Engineered Standards offer management a way to control work methods. Initially, standards may be used to select the best method for performing the work. After this has been done, work results should be compared to this standard to control the methods. Standard methods must include quality assurance steps and safety requirements.

2.6 Maintenance Performance

Maintenance work can be included in a standard. The cost performance of the maintenance department can be measured for labor productivity, material use, up-time, etc. Also appropriate allowances can be made in Scheduling Standards for maintenance functions. Thus, the costs at the work station level will include the necessary maintenance costs also. This data is especially useful when pricing work for the inside machine shop.

2.7 Scrap And Recovery Standards

Standards can be developed which would tell how much material should be used for a given part or product. With that information, the comparison of tots-l costs is more accurate. ALso controlling material usage through measurement against a standard prevents reduction in labor costs at the expense of increasing material expenditure. Sometimes increased total costs result when, in an attempt to minimize labor costs, supervisors are wasteful of material. cuttings are scrapped instead of being used for small parts. Paint brushes are discarded rather than cleaned to save clean-up labor costs. Many

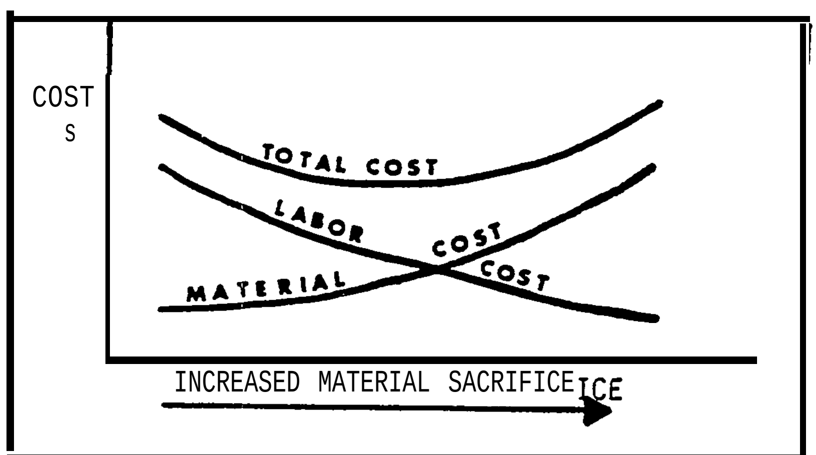


FIGURE A-1: IMPACT OF TOTAL COST OF MAKING LABOR SAVINGS BY SACRIFICING MATERIAL

examples of this problem exist -- and often the problem is one of not knowing what combination of labor vs. material usage gives minimum total cost to the shipyard.

2.8 Training

The background data used to develop standards includes a description of the best method, correct machine operations, safety, correct material use, and quality requirements. What better source of data for the training of hourly employees and their supervisors ? Kaiser Aluminum made it a practice to have the Industrial Engineers who developed the Process, Production and Scheduling Standards present training courses to operators and supervisors to show them how the work should be performed to result in the best possible cost performance.

2.9 Bidding

Traditionally cost estimates used in preparing bids for new ship construction are based upon the analysis of historical costs. This method is dangerous when the new design differs from the one that was used for the historical data. There is risk also if methods or facilities change. One of the potential uses of production and material standards is to assist in developing costs for a bid. Many parts of a ship lend themselves to being costed as standard parts.

2.10 Design And Production Engineering

One of the uses of standards which can really provide significant cost benefits to a shipyard is the use of standards for determining optimum ship design details. The

draftsman who selects design details has a very pronounced impact on the cost to build a ship. The Naval Architect selects major lines and ship configuration. The draftsman has the job of detailing that design, and his details largely determine the cost to install that part. If he had available to him a selection of cost-effective (labor plus material) parts to use, he would be able to incorporate them into the design. When a design is needed to develop a non-standard section, he could have construction standards available to him which would permit him to test the cost of alternative potential designs. This certainly would reduce the cost of the ship. There are two ship research reports which deal with this situation. One has just been published relative to designing and bidding.[1] The second is under preparation.[2] Both contracts are being administered by BIW.

2.11 Make-Buy Decision Making

Most shipyards do not have a systematic method for determining all the relative impacts of a make-buy decision. Often one of the weakest areas of the analysis is the cost of the alternatives. For example, determining the in-house "make" costs for an item which has traditionally been a "buy" item is normally difficult or impossible. Since the job was not previously performed, no history exists for this job. Standard Process times plus predetermined motion data can be used with accuracy to

[1] MacMillan - Improved Desing Process - op. cit.

[2] Glasfeld - Standard Structural Arrangements by G.D. Quincy on Task S-11.

answer the question of what will it cost to manufacture the item in-house.

2.12 Many Other Uses Exist

There are many other cost controlling ideas which can be used. Once engineered standards are built into a closed or integrated cost system in which all earned credits and all actual expenditures are recorded by a single closed system, many more sophisticated options are available. Shipyard managers can achieve control over their operations to a degree not presently possible. The potential for improvement is very large, and the nice thing is that nothing new has to be invented. All the techniques have already been tested and proven by some industry.

3. Standards Provide A Scientific Method For Predicting The Consequences

In the preceding subsection, it was seen how standards provide an analysis of-the method and resources that should be used to produce a given product. This subsection suggests another capability that a set of standards offers to management. Standards can provide answers to questions which start "What if we change ________?" By using the data developed through a standards program, it is possible to analyze with good accuracy the cost changes in "________" affected areas.

3.1 Facility Changes

Proposed new facilities can be evaluated using standard data. Some facility changes may be simple-enough to be classified as jigs or tools. Some facility changes are major and

involve costs of millions of dollars. However, in both cases, the stockholders are interested that the money be spent wisely and that they be assured of a reasonable return on their investment.

Usually jigs make a savings possible because they make it easier to hold parts in place or because they permit work to be performed in an easier manner (for example, permitting downhand rather than overhead welding by using a jig which rotates the piece). Most jig designers understand how to analyze the mechanical features that should be incorporated. Often several choices are available, depending on how much of the manufacturing process is to be encompassed by each jig. It is possible for a simple jig to be very cost effective, saving significantly more money than its cost. The use of standards to compare the alternative cost and savings of the choices helps to find the optimum payback rate.

Extensive changes in facilities should draw upon the same data bank of standards. Often facility changes address a single machine and the choice can be narrowed very qllickly.

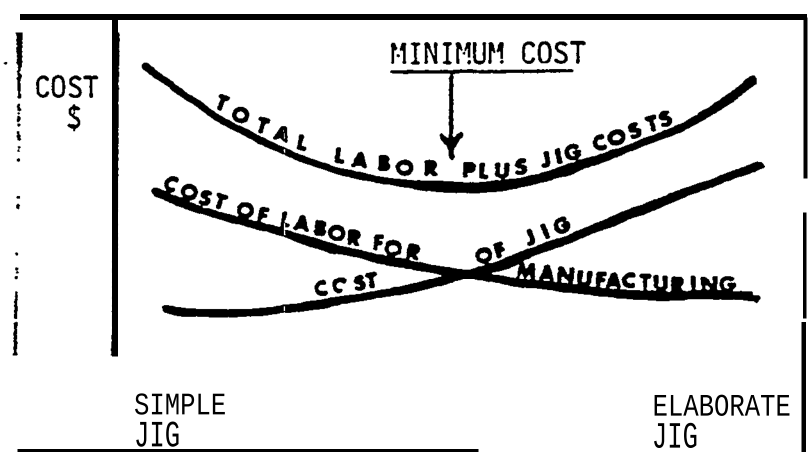


FIGURE A-2: JIG TYPES AFFECT TOTAL COST
Total cost to manufacture a part may be minimized by selecting the correct jig.

Facility changes reduce costs by substitution of new equipment for less efficient equipment or labor, or else

new facilities reduce cost by making possible a change in the fundamental process used to construct the ships. In the former case, the situation is completely analogous to the jig/ fixture example above. There is a larger sum of money involved and good management would insist upon more thorough analysis, but standards (either process of production) would be used to compare the impact of a facility change on ship construction costs. In the latter case, no historical basis exists for the comparison, and synthesis of data should be used for the cost comparison.

3.2 Ship Construction Process Iprovements

Process improvement is concerned with planning more effective work methods. There have always been persons who have sought to lessen the drudgery associated with various classes of work. However, such attempts were not really systematic until 1883 when Frederick Winslow Taylor revealed a new approach to the subject. He subdivided a task into elemental operations and examined each of these critically. Some of the points which need to be examined are:

- Is each step required or can some be eliminated?
- Can any of the required steps be combined?
- Can several of the steps be replaced by a less costly step?
- Would any savings be achieved if steps were performed in a different sequence relative to each other?

An analysis of layout, flow, materials handling, multiple activities, standardization of materials, standardization of

design, standardization of work methods, etc. , will determine if a process revision is warranted.

The standards which were developed for scheduling are built on detail data which can be used to answer such questions.

4. <u>Standards Encourage Management Control Over Operations</u>

We of the ways to make a manager very nervous is to hold him accountable for an operation which he does not feel is under his control. In order to control an operation he must:

a. know what is supposed to be done.
b. Know what is being done.
c. Be able to take corrective action when (b) does not match (a).

The use of an integrated cost system provides a manager with the most complete arsenal possible for establishing and maintaining the degree of control that permits him to operate efficiently and scientifically. The system should do three things:

a. Define the task.
b. Define the methods.
c. Define the resources needed.

Standards will permit the next step to be performed efficiently -- namely:

d. Evaluate the results.

The manager must analyze the ratio of resources consumed compared to the standard resources allocated. He must see if any variances are out of tolerance. Then he must decide what

course of action to take in order to improve. If most of the measurement is provided for him by means of the standards, he can operate in a “control by exception” mode, and conserve his managerial efforts for difficult problems.

5. Management Needs Standards For Planning And Production Control

The 0-2 task was designed to assist the shipyard manager who is beset with the multitude of external and internal problems. The real question that the research team felt had to. be addressed was one of what methodology could be used to solve expensive shipyard problems, thereby reducing the cost to build ships. Over 100 problems which plague shipyard managers were identified from the experience of the team members and through interviews of people at BIW and in other shipyards. An analysis of this list led to the conclusion that many of the most annoying problems were, in fact, subsequential or second tier problems which resulted because some primary problem was not recognized and solved in a timely manner.

The team then ranked the problems into a family tree to determine which problems were prime and which were subsequential or resultant. As pointed out previously, some typical items from the prime offenders on the list were:

- Inability to predict milestone completion dates accurately.
- Failure to fully utilize facilities. This manifests itself by constant fluctuations in the utilization of the equipment, overloaded one month and idle the next. It also is seen in the difficulty that some

shipyards have in knowing what their throughput would be under varying types of workload or work mix.

Capital expenditures have often been undertaken based on the “best guess” method of determining the probable savings which would result from the expenditure. There has not been the ready ability to answer the questions about “What if ?" which should accompany any decision for capital expenditures. Consequently, the return on the investment is not always maximized.

- Management is often unable to determine with certainty whether a cost reduction innovation resulted in the projected savings after it was instituted.
- Labor productivity is a subject near and dear to the heart of every shipyard manager. With so much of the cost of the ship tied up in labor, and this cost climbing with each new labor contract, the managers must know what the labor component <u>should</u> cost. The use of historical data for productivity measurement does not tell management what the cost should be. It includes all the inefficiencies that have taken place in the past. There is no way of culling these out of the historical data.

The search for the best solution to these very real problems led the research team to conclude that Planning and Production Control are one of the most important staff functions that exist in any shipyard. Also that the effectiveness of

production contro1 was greatly enhanced by good standards. And finally that good standards as developed to assist Planning and Production Control also gave a large assist to other areas of management control.

6. Integrated Cost System

Another beneficial use of engineered standards is to support an integrated or closed cost system. A closed cost system is one of the accounting techniques revealed by the . study of other industries. Under this concept, all expenditures are measured. These expenditures are compared to standard expenditures. Standard expenditures are based on the quantity of a product produced. A comparison of the actual cost and the standard cost is made and the resulting variance is charged to the managerial position which is capable of controlling the variance. For example, labor hours would be charged to the first level supervisor. These debit hours would be compared with standard hours earned by the work which the crew completed. The ratio of standard earned hours to actual paid hours is called Labor Productivity. This measurement is made continuously and reported frequently. The supervisor who keeps his crew gainfully employed on productive work will earn more hours and consequently his performance report will be superior to those who do not manage in this fashion. As a result, labor costs will be reduced. Table A-1 shows Labor Cost Accountability.

Similarly, other performances can be measured. Table A-2 shows a few of the possibilities in material cost.

NAME OF VARIANCE	SOURCE OF MEASURE OF ACTUAL	SOURCE OF MEASURE OF STANDARD	MANAGER ACCOUNTABLE
Labor Productivity	Hours of Time Earned as Used For Payroll	Earned Hours from Budget of Work Completed	First Level Supervision
Bid Labor Hour Forecast	Labor Hours Budgeted to Work Packages (By WBS Element)	Forecasted Labor Budget Hours Used in Bid (By WBS Element)	Bid Estimator
Labor Productivity Goal Achievement	Actual Total Yard Labor Productivities	Goal Yard Labor Productivity as Forecast for Bid	Yard Manager
Staff Work	Actual Work Goals	Planned Work Goal	Staff Member

TABLE A-1: INTE INTEGRATED COST SYSTEM-ACCOUNT *ACCOUNTABILITY* FOR LABOR COSTS *IS* CHARGED TO CONTROLLING ORGANIZATIONAL POSITION

NAME OF VARIANCE	SOURCE OF MEASURE OF ACTUAL	SOURCE OF MEASURE OF STANDARD	PERSON/GROUP ACCOUNTABLE
Quantity Used	Stores Issue Slips	Quantity Called for on Design Drawing	Shop Making Stores Withdrawal
Quantity Ordered	Quantity on Purchase Orders	Quantity Called for on Design Drawing	Buyer of that Item
Unit Price	Vendor Invoice Unit Price	Unit Price Used in Bid Calculation	Buyer of that i tern
Bid Item Quantity	Quantity of Item Used in Bid Preparation	Quantity Called for on Design Drawing	Item Cost Estimator

TABLE A-2: INTEGRATED COST SYSTEM-ACCOUNTABILITY FOR MATERIAL COST IS CHARGED TO CONTROLLING ORGANIZATIONAL POSITION

Material costs have traditionally been a very difficult expenditure to control because of a lack of accountability.

The same methodology can be extended to all controllable expenditures. Some standard is established. The actual performance to that standard is determined. The position with control over that expenditure is charged with this goal attainment. When Engineered Standards are used as the basis for rational evaluation, maximum results are obtained.

An integrated cost system exists when the determination of “standard” and “actual” can be placed into a single model with related values reflecting that relationship. Then measurement becomes coherent. The measurements are based on a single data bank. The total of all expenditures will follow from the record of all the parts of expenditures.

When all expenditures are charged to an accountable position, and the credits for work performed are awarded by the same system to the accountable position, a closed cost system results. This type of control functions best when the credits are based on engineered standards.

APPENDIX B

HOW AN ENGINEERED PROCESS STANDARD

IS DEVELOPED

APPENDIX B

HOW AN ENGINEERED PROCESS STANDARD IS DEVELOPED
A SAMPLE

Figure B-1 illustrates the steps that were followed in establishing process standards. The example used is the Exactograph Flame Cutting Machine. Sample material used in or developed during the various steps is contained in the supplementary exhibits. Steps 1-3 are critically important in establishing the proper management and labor frame-of-mind which is absolutely essential to the success of the project.

1. Management must understand what is to be done, and what they will have to do with the results. A memo should be distributed by management stating the objectives and establishing organizational responsibilities involved. Program management controls over schedule and budget should be settled.

2. Study team should be commissioned and introduced to the people they will contact including anyone who may be involved in the time study phase.

3. The production process must be understood before any standard setting is done. It often clarifies this step if operating procedures are published. Quality standards should be spelled out with written maximum and minimum levels of acceptance.

4. The capability of the work center must be published.

5. Allowances must be made on an elemental basis for unusual circumstances, such as heat, smoke

ventilation, cramped position and fatigue. Time must be included for break time permitted by management.

6 The time required to perform the-required work to complete the process is determined. Various methods of determining this time may be used. Direct watch readings, taken by a qualified time study man, will give excellent results. Normally, Industrial Engineering Pace Rating should be used. For machine . operations under control of the operator, such as burning or welding, additional testing should be done to ensure that optimum speeds are used. Will higher speeds cause a defect? Can the standard speed be maintained over the full range?

7 The Production Standard should be written which will give credit for all necessary work and will permit the measurement of work station productivity. The format is determined by the nature of the data reporting actual work performed.

8 A Scheduling Standard should be developed to aid the work of the Planning Department. Again, the format is determined by the application methodology.

9 & 10 Schedule & Productivity Performance should be reported.

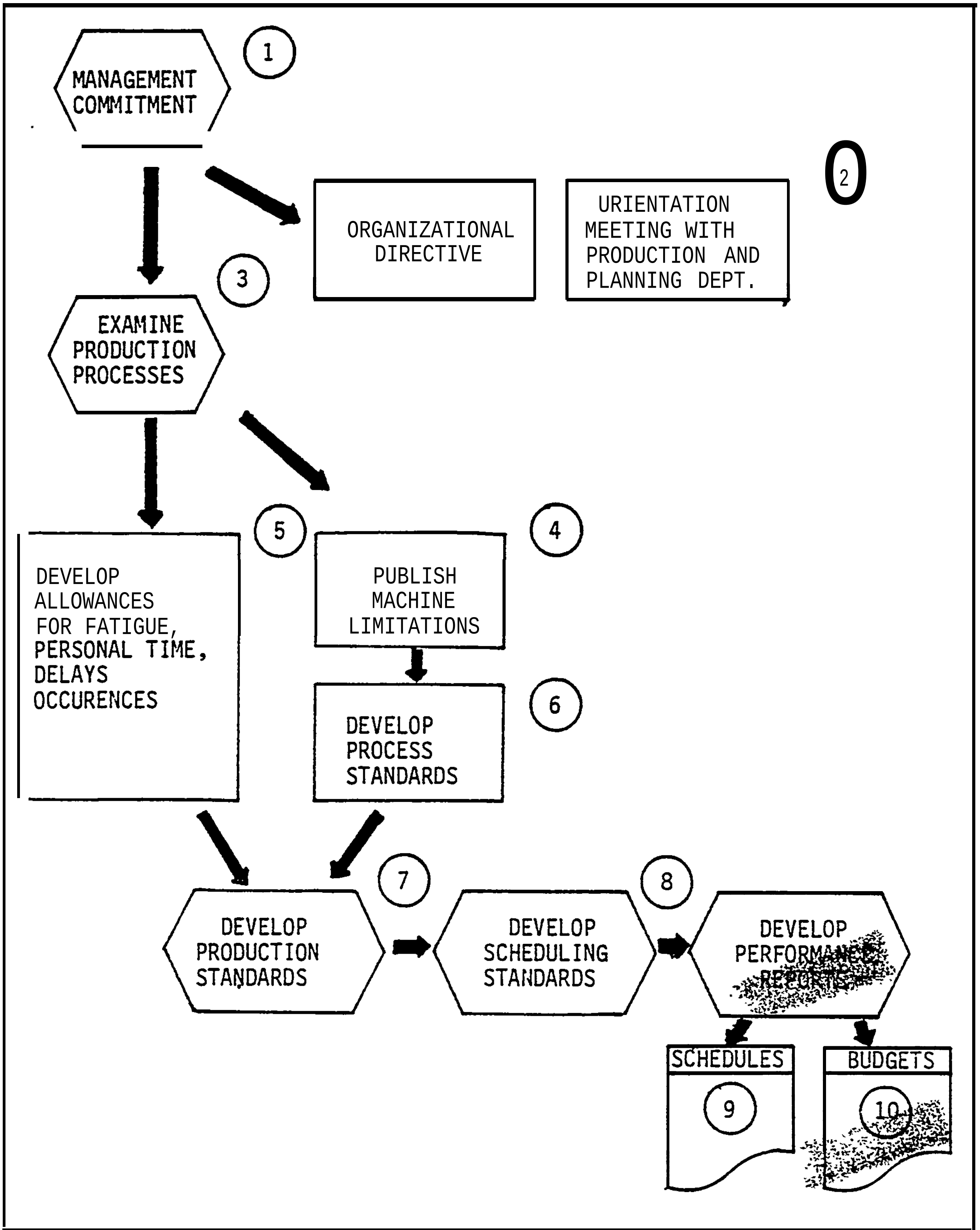


FIGURE B-1: PROJECT MANAGEMENT DIAGRAM FOR THE DEVELOPMENT OF SCHEDULING STANDARDS

O = **Identification number of attached illustrative exhibit**

EXHIBIT 1

OUTLINE OF ITEMS COVERED AT MEETING
WITH YARD MANAGEMENT

SUBJECT : ESTABLISHING ENGINEERED PLANNING AND SCHEDULING FOR THE FABRICATION PLANT

1. GOAL

To improve management control over schedule performance - and labor costs through modifications to the data bank, the scheduling system and the reporting system used by production control in the fabrication plant.

II. METHOD - PROPOSAL

A. Improve accuracy of planning forecasts by using engineered standards to schedule load at all work stations.

B. Measure work station schedule performance.

C. Determine ❑an-hour content of required work and develop engineered standards for performance measurement.

D. Develop necessary reporting system and measure labor productivity at the lowest level of accountability.

III. EXPECTED IMPROVEMENT IN SCHEDULE PERFORMANCE

A. Present level of schedule compliance.

B. Anticipated level of schedule compliance.

C. Benefits from achieving B.

EXHIBIT 1 (Cont'd)

D. Costs to achieve B.

IV. EXPECTED IMPROVEMENTS IN PRODUCTIVITY

A. Present levels of labor productivity.

B. Potential levels of labor productivity.

C. Savings in labor costs.

D. Other benefits.

E. Costs to establish, maintain and apply standards.

V. PROPOSED ORGANIZATIONAL RESPONSIBILITIES AND ACCOUNTABILITIES

A. During study period.

B. After study period.

VI. SCHEDULE OF ACTION STEPS FOR CONDUCTING STUDY AND IMPLEMENTARY RESULTS

A. Getting the support of supervision.

B. Assemble necessary team of skilled people.

C. Cost and schedule milestones.

VII. DISCUSSION OF POTENTIAL PROBLEMS AND THEIR MITIGATION

VIII. ACTION REQUIRED FROM YARD MANAGER

A. Charter letter.

B. Progress review meetings.

C. Visible support.

EXHIBIT 2

OUTLINE OF TALK WITH SUPERVISION AND WITH HOURLY WORKERS

IMPROVEMENTS IN PLANNING & SCHEDULING

SUBJECT : IMPROVEMENTS

I. Brief introduction of each person on team -- quick positive biographical comment.

II. Outline Objectives -- Be positive about benefits to the audience. Mention the obvious odious features.

III. Explain how objectives are to be achieved. Listen for feedback which might contain helpful information. Answer questions and encourage discussion.

IV. Explain team conduct (see attachment).

V. Explain to audience what their role is.

VI. Ask for their aid.

VII. Answer questions.

EXHIBIT 2 (Cont'd)

GUIDELINES FOR TEAM CONDUCT

Do not interfere with in process work.

Observe present conditions.

Stand out in the open. Do not study people unless you tell them first that you are going to do that and what you are going to observe. If you do not know the operator be sure--that his supervisor introduces you and tells the man what you are there for.

Show your study sheets and explain them to the operator and supervisor involved if either one asks to see them.

Document how the work was done.

Pace rate each element.

Share results first with the supervision involved.

EXHIBIT 3

EXAMINE PRODUCTION PROCESSES

(Instructions given to operator so that operations follow *a* repeatable sequence for observing/measuring operations).

OPERATING DESCRIPTION

Of Work Covered By Standard On
Exactograph Flame Planer
PC418

As Used In Establishing

Production And Scheduling Standards

EXHIBIT 3 (Cont'd)

MACHINE

Exactograph Flame Cutting Machine

PARTS COVERED

Steel Plates

OPERATION

Set Up
Burning
Plate Handling

ALLOWED TIME AND DIMENSIONS

All times are in minutes and hundredths of a minute.

Distance in feet and inches.

ANALYSIS

Variables: Plate thickness, length of plate, amount of slag to be removed, speed of cuts, paint thickness, tips, paint composition, desired edge cut, angle or square cut, number of passes per side.

TOOLS REQUIRED

Spare tips, cleaning brush and tip cleaners, combination Square, tip wrench, soap stone, hand strikers, paint and brush.

PLATE HANDLING

Plates are loaded and unloaded with a 16-ton magnetic crane.

EXHIBIT 3 (Cont'd)

MACHINE CAPABILITIES

The flame planer machines are capable of burning and double beveling sides and ends of one 14′ x 90′ plate internally. The main bridge for side cutting is equipped with two torch carriages with free floating heads and triple torches. The two auxiliaries are each equipped with one torch carriage with free floating heads and triple torches for bevel cutting.

BEGINNING AND END POINTS

1. Set-Up Main begins with "position main bridge" and ends with "start of edge cut."
2. Set-Up Auxiliary begins with "position auxiliary bridges" and ends with "start of end cut."
3. Hand Burn Scrap begins with "obtain torch" and ends with "aside scrap."
4. Chip Slag begins with "obtain scraper" and ends with "visual inspection."
5. Mark Plate For Identification starts with "obtain paint and brush" and ends with "aside paint and brush."

PROCEDURES

When the plate length is not adequate to allow auxiliary 1 and 2 to cut internally to the main bridge, the first cut will be with auxiliary 2 and will be external time. Main bridge set-up will be done internally to auxiliary 2 burn. Following auxiliary 2, start main, set-up and start auxiliary 1. Perform

scrap functions internally as time permits.

If one end requires two passes (i. e., to obtain a bevel and 60° chamfer undercut) and the other end requires only one pass, the single pass end will be burned first by auxiliary 2 to minimize the -interference between the main bridge and auxiliary 2.

EXHIBIT 4

MACHINE LIMITATION

APPROVED

NO. PC 418

DTD. Rev. September 1975

ASSET NO. 5119

MACHINE CAPABILITIES

HARDINGS PLANT

Exactograph Flame Planer

	Length	Width	Thickness
Max. incoming plate size:	90'	14'	4"
Min. incoming plate size:	9'	2'	1/8"
Max. size of finished part:	70'	13'-9-3/4"	4"
Min. size of finished part:	4'	6"	1/8"

Min. edge trim: 1/4" per side on cut plate
Max. edge trim: 137-3/8"

Number of heads: Main bridge 2 triple torch; Each of two aux. bridges 1 triple torch

Machine speeds: High Speed Travel 40-980 IPM
Drive System 4-65 IPM

Rail length: 101'

Parking Space: East Aux. 7'
West Aux. 7'
Main Bridge - 15'-6"

Tolerances

Width ± 1/16 in 40'

Length ± 1/8 in 40'

<u>EXHIBIT 4 (Cont'd)</u>

Edge preparation single pass:
square, bevel over up to 45°, bevel under up to 45°, double bevel up to 45° each X or K cut.

Separate pass needed for bevel under 60° and/or 4:1 chamfer.

Notes:

(1) Minimum distance between main torches for square or bevel under is 16".
(2) Torches in one head can adjust to strip from 7" to 11½" wide. Can burn one, two, or three at one time.

EXHIBIT 5

ALLOWANCES

Personal allowance based on 480 minute shift:

2% =	10 Minute Morning Break
5% =	24 Minute Personal
5 % =	24 Minute Miscellaneous And Interferences
12%	TOTAL

1975-03-31
C. Munsey

EXHIBIT 6

INDUSTRIAL GAS

PLT FHK. NCHES	TIP SIZE No.	CUTTING SPEED IN/MIN	OXYGEN CUTTING Press. P. S. I.G.	OXYGEN PREHEAT PRESS P. S.I. G.	MAPP GAS PRESS P. S.I.G.
1/4	68	24-31	60-70	5-10	2-10
3/8	65	23-30	70-80	5-10	2-10
1/2	60	22-29	80-90	5-10	2-10
3/4	56	20-26	80-90	5-10	2-10
1	56	18-24	80-90	5-10	2-10
1-1/4	54	16-22	70-80	10-20	2-10
1-1/2	54	15-20	80-90	10-20	2-10
2	52	14-19	80-90	10-20	2-10
2-1/2	52	12-17	80-90	10-20	4-10
3	49	10-14	80-90	10-20	6-10
4	44	9-13	80-90	10-20	6-10
6	44	7-11	80-90	10-20	10-15
8	38	6-9	80-90	15-30	10-15

Performance Data for HS (1 piece) and FH (2 piece)
High Pressure Cutting Tips

Cutting oxygen pressures at the torch. All recommendations are for straight line cutting with 3 hose torch perpendicular to plate.

Preheat pressures measured at regulator based on 25' maximum of 5/16" I.D. hose. Preheat oxygen 10-30 P.S.1.G. (injector torch).

Information from MAPP ADG-MAPP 1026
4-73-50M-1327

EXHIBIT 7

STUDY SHEETS FOR DEVELOPMENT OF STANDARDS

Includes:

EXHIBIT 7 (Cont'd)

WORK STEPS

Ref.		
1.	Check paper work.	Compare daily sequence sheet to daily write-up sheet for plate size and job number. Job number identifies B/M summary sheet for cutting instructions and dimensions.
2.	Load and position plates.	Crane lowers plate on skid and slides against plate guides. Plate guides are operated from control panel on main bridge.
3.	Measure length (st1. tape).	Operator measures length of plate with 100' steel tape and small hand magnet. Stl tape is secured on one end of the plate and walked the length of the plate to verify adequate stock.
4.	Position main bridge (30')*, set torches for parallel check.	The main bridge is moved to the finish end of the plate. Torches are set to approximate width dimension. *Distance talc. 10' required west skid, 50" required east skid. Ave distance = 30'.
5.	Check parallel (main bridge)	Bridge is motor driven at 65 F.P.M. the full length of plate, at the same time the operator walks backwards and visually checks runout to verify adequate stock for required width for burn.

"EXHIBIT 7 (Cont'd)

6.	Set-up for straight and/or angle cuts.	For straight cutting, the set-up consists of checking center torch for vertical level and set for correct width cut. Angle set-up 60° and less for over bevels can be obtained by positioning bevel torches into slots of pre-set guides of 22½° 30°, 45°, and 60. Angles of greater than 45° or chamfers of 4 to 1 for under cutting must be done by removing burning tip and adding pre-set extended torch head. Under cuttin must be done after a straight cut for desired width has been done. (i.e., a second pass.)
7.	Ignite Torch(s) and pre-heat.	The torches are ignited by hand switches. Bridge is moved into start position allowing for pre-heat prior to cutting.
8.	Preliminary cut, check measurement and set-up.	Cut into scrap part of plate, aside bridge, measure with steel tape for accuracy and adjust if necessary.
9.	Start main cut.	Start bridge and dial speed.
10.	Walk and obtain Aux #2 (approx. 55')	Walk from the start end of plate to west end of skid for auxiliary bridge #2. (see note #1)

EXHIBIT 7 (Cont'd)

11. Position Aux #2 (15').	Hand push aux. #2 (15') at 65. F.P.M. to the finish end of plate. (see note #1)
12. Ignite torch(s) Aux #2.	See reference #7
13. Set-up (Straight and/or Angle) .	See reference #6
14. Preliminary cut and check.	For straight cuts and over bevels or under bevels of less than 45° checking can be visual. For preliminary cuts of over 45° and chamfers of 4 to 1 check by cutting into scrap part of plate, aside bridge, check, adjust if necessary.
15. Start final cut.	See reference #9.
16. Walk and obtain Aux #1 (approx. 115').	Walk from finish end of plate to Auxiliary #1. (see note #1)
17. Position Aux #1 (60').	Hand push Aux #1 to start end of plate approx. 60' at the rate of 65 F.P.M. (see note #1).
18. Ignite torch(s) Aux #1.	See reference #12.
19. Set-up (Straight and/or Angle).	See reference #13.
20. Preliminary cut and check.	See reference #14.
21. Start final cut.	See reference #15.
22. Obtain hand torch (15').	Climb on plate and walk to main bridge for hand torch. Ignite from main torch.

EXHIBIT 7 (Cont'd)

23.	Hand burn scrap.	Cut edge scrap, both sides, into 4' lengths and let rest on railroad irons.
24.	Aside Torch (6').	Turn off torch and return it to main bridge.
25.	Aside Scrap.	Lengths of scrap on right side of plate are put into scrap trays located an average of 3' on right side under skids. Scrap on left side is slid across" plate and put into trays. Average distance of 13'.
26.	Hand chip slag (straight).	Operator removes slag with hand scraper.
27.	Hand chip slag (angle).	Same procedure as straight removal except amount is greater and more time is required.
28.	Return to Aux #2 (40').	Walk 40' to Aux #2 at finish end of plate. (see note #1).
29.	Stop and aside Aux #2 (approx. 15').	Lock floating head to prevent dropping over end of plate. Shut down machine. Hand push bridge to west end of skid. (see note #1).
30.	Return to Aux #1 (60').	Walk approximately 60' to Aux #1 at start end of plate. (see note #1).
31.	Stop and aside Aux #1 (approx 60').	See reference #29.

EXHIBIT 7 (Cont'd)

32.	Obtain hand torch (85').	See reference #22.
33.	Hand burn scrap.	See reference 23.
34.	Aside torch (6').	See reference #24.
35.	Aside scrap.	See reference #25.
36.	Hand chip slag (straight).	See reference #26.
37.	Hand chip slag (angle).	See reference #27.
38.	Return to main (15').	Walk approximately 15' to main bridge at finish end of plate.
39.	Stop and aside main (60').	Lock floating burning heads to prevent dropping over end of plate. Stop all functions of main by pushing stop <u>all</u> button of control panel. Turn on high speed travel at 65 FPM and walk 115' to position main for next plate (see note #2).
40.	Aside scrap.	See reference #25.
41.	Hand chip slag (straight).	See reference #26.
42.	Hand chip slag (angle).	See reference #27.
43.	Hand paint piece marks.	Walk, to main bridge for paint and brush approximately 60'. Return to start end of plate (60'). Paint job number and next location and repeat for finish end. Return to main bridge (115').

EXHIBIT 7 (Cont'd)

44. Aside Plate — The magnetic crane removes finished plate from skid.

General Notes

1. The distances for the auxiliary bridges were measured while plates were being burned on the west skid. When plates are to be burned on the east skid, the distances remain the same but they apply to the opposite numbered auxiliary machines.

1. For reference 39, delete 115 and insert 15'when burning plates and starting on the east skid.

EXHIBIT 7 (Cont'd)
JOB METHOD TICKET

Flag

Task - LOAD BURN SKIDS WITH PLATE

Std.No. 2

Page 1 of 1

Date 3/17/75

Standard -

Work Location - [ ] Shipboard [ ] Shop [X] Hardings

Applicator D.W.

Ref.	JOB ELEMENTS	Units	Time per occ.	occ. per Load	Tot. Min
	Dismount from Skid - 1'		.0125	1	.0125
	Walk 15'		.0045	1	.0675
	Signal Crane Operator			1	0.13
	Enforced Delay for Crane Move			1	2.500
	Walk To Load 15'			1	.0675
	Push on Plate To Center	30 Pounds			0.130
	Signal Crane		.10	1	0.100
	aside - & Return 5'-ow	Feet	.0045	1	.045
	Mount Skid 1'				.0125
	Pick up Tape.. Measure & Magnet -				0.20
	Affix Tape To Plate				0.13
	Walk length of Plate 40'				0.180
	Read Tape				0.26
	Read Sketch				0.52
	Walk To Magnet - 40'				0.180
	Pick up Magnet				0.10
	affix Tape with Magnet				0.13
	Walk Width of Plate -10'				0.045
	Read Tape				.26
	Check Sketch				0.52
	Walk To Magnet				.045
	Check Plate thickness with Tape				0.26
	Mark List				0.13
	Aside Tools				0.40
	Walk To Burning Machine Control Position				0.45
				Total this page	

EXHIBIT 8

SNAME - MARAD

02 PROJECT

SCHEDULING STANDARD

DEPARTMENT: 34 HARDINGS AREA 50

OPERATION: BURN PLATES WITH EXACTOGRAPH

MACHINE : EXACTOGRAPH FLAME PLANER #418

PRODUCTION CENTER
NUMBER : 418-S

REVISION NUMBER:

REASON FOR REVISION:

Effective Date: 8/10/75

Superseded Date: __________

Issue Date: __________

EXHIBIT 8 (Cont'd)

Section A - Occurance Allowances

Hours	
31	Check paper work and set-up main bridge
+	.09 additional set-up for each 60° under or 4:1 (longitudinal burn)
+	Burn time length, each pass from-table
+	.09 set-up each external width 60° under or 4:1
+	Burn each external width pass
	TOTAL
+ 12%	(2% empty scrap tubs and 2% clean machine 1 per 3 shifts 8% fatigue)
	Total allowed hours

Section B - Application of Occurance Allowances

Add .31 hours for loading and main bridge set-up.

Add .09 hours for-each 60° under or 4:1.

Based on plate thickness and burn length, add the longitudinal burn time-from the attached table.

Add the burn time for external butt passes if required as determined by the instruction in "Internal Burning of Ends."

Add 12% to this total for allowances.

Section C - Allowances

Allowances for shift start up and clean up, fatigue, personal relief, and miscellaneous delay totaling 10% are included.

Section D - Direct Crew

This standard is based on (1) Machine Operator.

Section E - Material Handling

Time is included for load and aside plates and for scrap tub removal, but the crane-operator's time is not included.

EXHIBIT 8 (Cont'd)

418-S Oct 7, 1975

PLT THK	Black or Paint IPM	TIP	IZ IPM	TIP	30° IPM	TIP	30° IPM	TIP	45° IPM	TIP	45° IPM	TIP	30° IPM	TIPS	30° 30° IPM	TIPS	30° 30° IPM	TIP	30° 30° IPM	TIPS	4-1 IPM	1/8" incre	60° IPM	1/8" incre
1/4	31	60/72	20	60																	19	1	28	1
3/8	27	60/72	20	60	25	60	20	60	20	60	19	60	20	72/60							17	2	25	2
1/2	24	65	20	56	20	56	16	54	18	54	18	54	18	60/56	16	60/56	18	72/60			14	3	20	3
3/4	23	68	19	56	19	54	15	52	17	52	16	52	17	56/54	15	56/54	17	60/54	13	40 40 31	10	4	19	4
1	21	54	19	54	18	54	14	52	16	52	15	52	15	56/54	14	56/54	16	60/54	11	43 40 43	9	5	18	5
1 1/4	19	54	17	54	16	54	13	46	15	46	14	46	13	54/52	13	54/52	15	54/52			8	6	16	6
1 1/2	17	52	15	54	14	52	11	46	12	46	13	46	11	54/52	12	54/52	14	54/52	10	60 40 52	7	7	14	7
1 3/4	15	52	13	52	13	52	10	44	11	44	11	44	10	54/52	11	54/52	11	52/46			6	8	13	8
2	13	52	11	52	11	49	9	44	9	44	8		9	52/49	0	52/49	0	52/46	9				11	9
3	12	49	10	49	9	44	8	44	7	44				49/44		49/44	8	46/44	8	60 60 60	4		9	10
4	10	44	8	44	8	44	6	35	6	35	6	35	6	/44	6	/44	6	46/44					8	11
6	6	35	6	35	6	35	4	35	4	35	4	35	4	44/35	4	44/35	4	44/35					6	12

EXHIBIT 8 (Cont'd)

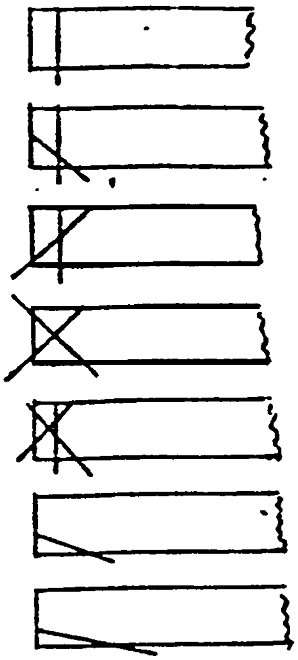
418-s

Rate IPM	Hours Per Burn Length Shown In Feet													
	5	6	7	8	9	10	20	30	40	50	60	70	80	90	100
8	.138	.165	.192	.220	.248	.275	.55	.825	1.10	1.37	1.65	1.93	2.20	2.48	2.75
10	.110	.132	.154	.176	.198	.220	.440	.660	.880	1.10	1.32	1.54	1.76	1.98	2.20
12	.092	.110	.128	.147	.165	.183	.367	.550	.733	.917	1.10	1.28	1.46	1.65	1.83
14	.079	.094	.110	.126	.141	.157	.314	.471	.629	.786	.94	1.10	1.26	1.41	1.57
16	.069	.082	.096	.110	.124	.138	.275	.412	.550	.687	.83	.97	1.10	1.24	1.38
18	.061	.073	.086	.098	.110	.122	.244	.367	.489	.611	.73	.85	.98	1.10	1.22
20	.055	.066	.077	.088	.099	.110	.220	.330	.440	.550	.66	.77	.88	.99	1.10
22	.050	.060	.070	.080	.090	.100	.200	.300	.400	.500	.60	.70	.80	.90	1.00
24	.046	.055	.064	.073	.082	.092	.183	.275	.367	.458	.55	.64	.74	.83	.92
26	.042	.051	.059	.068	.076	.085	.169	.254	.338	.423	.51	.60	.68	.77	.85
28	.039	.047	.055	.063	.071	.079	.157	.236	.314	.393	.47	.55	.63	.71	.79
30	.037	.044	.051	.059	.066	.073	.147	.220	.293	.367	.44	.51	.58	.66	.73
32	.034	.041	.048	.055	.062	.069	.138	.206	.275	.344	.41	.48	.55	.62	.69
34	.032	.039	.045	.052	.058	.065	.129	.194	.259	.324	.39	.46	.52	.59	.65
36	.031	.037	.043	.049	.055	.061	.122	.183	.244	.305	.37	.43	.49	.55	.61
38	.029	.035	.041	.046	.052	.058	.116	.174	.232	.290	.35	.41	.46	.52	.58
40	.028	.033	.038	.044	.050	.055	.110	.165	.220	.275	.33	.39	.44	.50	.55

ABOVE HOURS INCLUDE 10% ALLOWANCES

Edge Preparations

EXHIBIT 8 (Cent’ d)



s q .

Bevel ”Under (Also with square)

Bevel Over Also with square)

Double Bevel “X”

Double Bevel w/land “K”

Bevel Under 60°

4:1 chamfer

Each of the above edges rcquire one pass.

Calculation of standard Time

1. Determine quantity of pieces to cut from the plate.
2. Select time for length pass from table that corresponds, to the length - of burn, thickness of plate and edge.. preparation. Use the slower burn rate if the edges vary in preparations.
3. Select the appropriate set-up times for the specified edge preparations.
4. Repeat (1) and (2) if more than one length pass is needed.
5. Determine the end passes that can not be performed internal to the main burn: see Internal Burn of Ends. Select time for cach external pass. Common line burn is used for adjacent square.butts of two pieces.

5. Select the appropriato set-up times for each external pass

7. Add together the time to check paper work, set-up, burn plus allowancas.

Section F - Procedure Description

Internal Burning of Ends

At least One butt pass is performod internal to the main bridge longitudinal burn. To dotermine how many other butt passes can be performed internal to the main add 12 feet to the length of each butt pass plus 4 feet. Accumulate one at a time, the length plus 4 feet for each pass. Each new total that does not exceed the overall length of the plate is another pass that can be done- internally. Each pass that exceeds the length will be performed external to the main burn, therefore adding to the overall time to burn the plate. The functions of burning scrap, aside scrap and chip slag are considered internal to the burning also. There is usually enough idle time during burning to perform these tasks since the time per foot of burn averages .23 minutes. For a 10′ x 40′ plate the time needed to take care of scrap and slag is 23 minutes.

The reason butt passes can be burned internal. when plate length is greater than 12 feet plus butt pass length plus 4 feet is:

1. 12′ 1/2″ minimum distance between Aux 1 and main bridge torches
2. the length of the butt pass is offset by the comparable distance traveled by the main bridge
3. adding four feet offsets the distance traveled by the main bridge during the set-up and preheat for the width burn.
4. one butt can always be burned internal by Aux 1 because the butt can be burned without any chance of interference with the main bridge since the main bridge is moving away.

EXHIBIT 8 (Cont'd)

Section G

APPROVALS:

Prepared By: C. Lamb 8-20-75

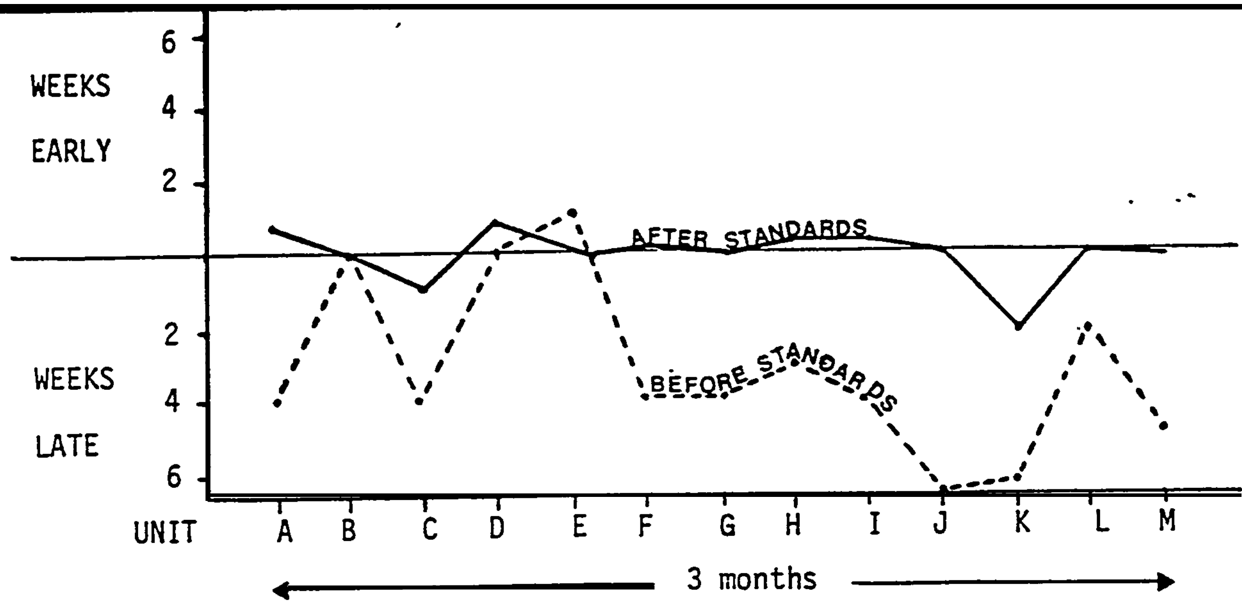
Reviewed By: ____________

Dept. Supv. ____________

Plant Supt. R Hilwen

02 Proj. Mgr. : JAB II 2-4-6

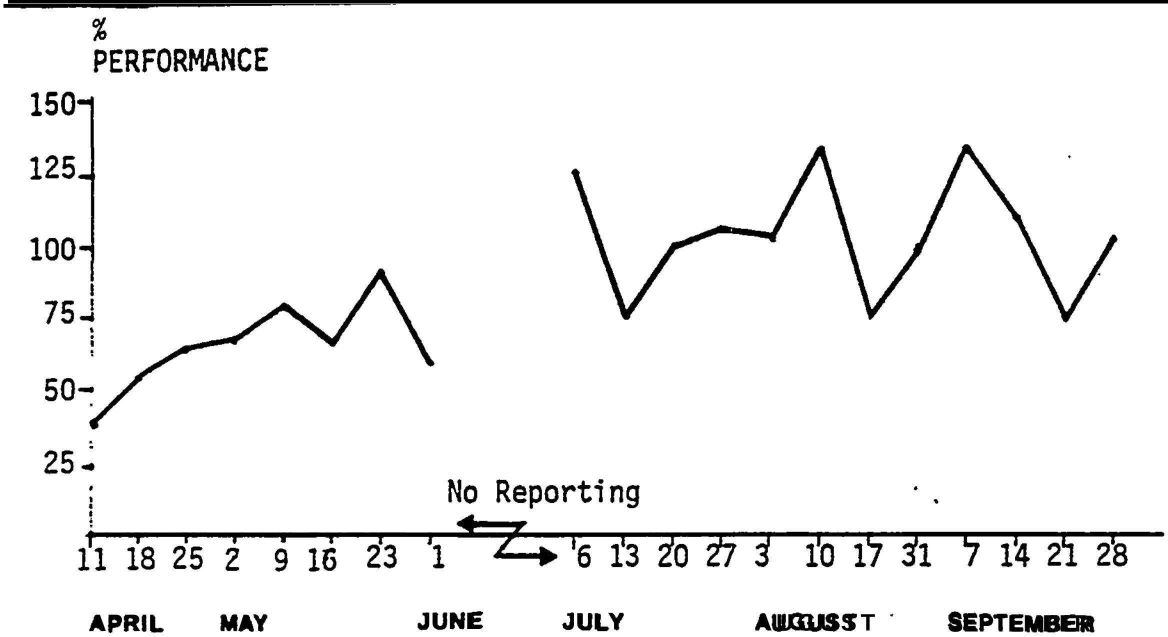
EXHIBIT 9



IMPACT OF STANDARDS IN SCHEDULE COMPLIANCE
In three months, use of standards for shop scheduling reduced average time late to zero weeks.

EXHIBIT 10

PERFORMANCE-TO-STANDARD REPORT



FLAME PLANER BUDGET PERFORMANCE (1975)

APPENDIX C

LITERATURE SEARCH AND SHIPYARD SURVEY

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LITERATURE SEARCH AND SHIPYARD SURVEY

1. Point of Departure

There were two basic facts which prompted the review of literature on Planning and Production Control and the survey of selected foreign and domestic shipyards.

> Foreign shipyards had significantly higher productivity coefficients than U.S. shipyards. Impact of regulatory agencies, design characteristics, production facilities and other external influences on cost of U.S. shipyards was too small to account fully for the difference.
>
> Domestic heavy manufacturing industry had consistently higher profit margins than U.S. shipyards even though the basic processes of production were generally the same.

The survey of the literature and the foreign yards was conducted to identify reasons for these two basic facts; and to determine what steps the U.S. shipbuilding industry was taking in improved planning and production control methods to redress these imbalances.

2. Literature Search - Shipyard Improvements In Planning And Production Control

The literature search was conducted to determine what

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1 TASK 0-2 - "Results of Literature Search of Technical Papers and Reports on Planning, Scheduling, Cost Estimating and Cost Control of Shipbuilding," undertaken by Bath Iron Works Corporation under MarAd Contract 3-36233.

steps were being taken by the shipyards to improve performance in each of the four basic areas. In general, the steps being taken divide into two basic categories:

- Mechanical - Introduction of new aids, primarily computers and related devices, to assist in performing traditional functions.
- Methodological - Introduction of new methods to supplant old methods of Planning and Production Control.

2.1 Mechanical Changes

Most changes in Planning and Production Control reported by the shipyards in the literature fall into the mechanical category and typically involve the application of computers for traditional data collection, record keeping and reporting functions. The objective of these changes has been two-fold:

a. To provide more timely data for shipyard management.

b. To reduce the clerical cost of performing these functions.

Motivation for more timely data (item a) has been the increasing emphasis on tighter financial management of the shipyards, in conjunction with a recognition of the significant time delays between the incurrence of cost in production and availability of information on these incurrences to management for actions. With manual reporting, delays of a week or more were very common; with computer reporting, delays were cut to one or two days. Delays are reduced to minutes or hours when

on-site terminals are used for collection of data at source and inquiry terminals are available in the shipyard offices.

The Planning and Production Control subfunctions supported by computers are largely constrained to progress and cost collection functions. The computer data base does contain plan and schedule information, but this information is manually prepared and manually entered primarily for use as reference benchmarks against which actual cost and progress data can be compared and variance information produced. Maintaining information on status of material illustrates this usage.

The second objective of mechanical innovations is reducing clerical costs. Clerical costs had tended to go up rather than down following expansions of computers into the Planning and Production Control area. First, since the computer could process and retain large volumes of information, it was programmed to do so and to produce voluminous reports. Little attention was given to the nature of management's need for information. Report volumes and content were mismatched to their usage as shown graphically in Figure C-1. Middle management needed more clerical assistance to digest the volumes of information they received into usable form. At the same time, first level supervision did not have the detail they needed to be effective.

Manual preparation of data for computer input and distribution and use of reports has typically increased clerical functions rather than reduce them. Results in reaching the second objective have therefore been disappointing although

the increasing use. of terminals is now beginning to reverse this trend.

It was generally concluded by the Study Team that although more and timelier data is available with the increased use of computers, little improvement has been made in the Planing and Production Control function itself from changed mechanics.

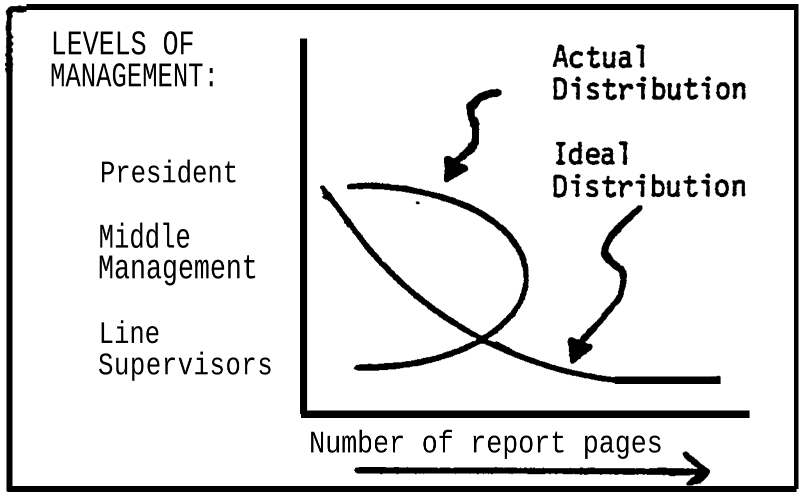

FIGURE C-1: REPORT DISTRIBUTION

2.2 Methodological Changes

Methodological changes are changes in the methods of Planning and Production Control, i.e., the logic that is employed. Although computers may be used to implement methodological changes (and frequently are the only available vehicle for processing entailed), it is the logic of the change that is important rather than the implementation vehicle.

During the 1950's and 1960's program management techniques were developed for managing complex weapon system development programs like POLARIS and the space programs. These techniques focused on the planning and scheduling problems which involved breaking a complex system into manageable parts (work packages) and establishing network schedules for identifying time-dependent predecessor-successor relationships and for highlighting

critical activities and events.

During the 1960’s these techniques migrated into other Navy ship construction programs and finally into commercial ship construction programs. All shipyards surveyed now employ a work breakdown structure and many use network scheduling. Work packages (or equivalent) are used as the basic vehicle for collection of cost data in all shipyards. Wherever network schedules are used, computer assistance becomes mandatory whenever the number of events and activities exceeds a few hundred.

Use of these program management techniques has made some improvement in Planning and Production Control in the shipyards, but for shipyards this was really limited to manipulation of the networks. Budgets could be automatically spread by computer over the time span of each network activity, and weekly loading could be calculated by trade or by shop or by both. Schedulers now had a fairly efficient tool by which they could test alternative plans and then select the best one to use.

The network/budget/schedule data bank that was accrued was then computer interrogated to issue work authorizations, budgets and schedules. It also was capable of ingesting schedule completion information and generating schedule performance reports, late parts lists, etc. The computer could give budget performance on work completed and even predict performance at some future time.

However, this network manipulation was only the transition step which could have led from data mechanics to Operations Research. The shipyards have not taken this next step in production control.

One internationally known marine machinery manufacturing firm went so far as to have schedule and budget progress on line full time. The craftsmen clocked in and out at the work centers using magnetically encoded badges. Each job order was clocked in and out at each operation and a piece count recorded for EDP use. Daily status reports were run early each morning. In addition, if the plant manager wanted up-to-the-hour information he had only to request a new printout of status and it would reflect the current situation.

Up to this point innovations were limited to data manipulation under the direction of the computer programmer. A new set of planning rules were eventually developed which permitted the planner to benefit from the calculating ability of the computer. Given certain schedule constraints to meet, the computer would seek to optimize the use of a resource, such as an assembly hall or a building basin. Start/finish dates were developed along with material needed dates, floor space utilization, material lists, machinery schedules, etc., all available either in hard copy or by Cathode Ray Terminal.

With all this power available to the planning department for both data storage and retrieval and now even data manipulation, one fatal weakness became increasingly obvious. Basic data input must be accurate. The computer had learned precise planning rules. The logic of the system had overpowered the

planner. His years of experience had taught him how to compensate for less than precise data, how to make the ship come out right even if the information available to him was not quite accurate. The computer was a victim of its diet and could not exercise the same kind of judgement.

Quite obviously unless a source of more precise data could be obtained, the improvements now available would not succeed in materially improving Planning and Production Control in shipyards.

The systematic advances offered much greater potential in that they were directed at a much larger problem; that of finding, testing and utilizing plans which were improvements over the manually devised plans. These advances were not limited to doing better what was already being done. These advances were directed at finding better things to do. True, these advances would need to fully use the technical data management innovations -- but more was required.

2.3 Conclusions Reached From Literature Search And Shipyard Surveys

Neither the literature search nor the shipyard survey revealed the advances in production control methodology that the research team had sought. Although the innovations were in themselves reasonably successful, their lack of successful application in shipyards was the result of the shortage of good input data, and not because the systems advocated were unable to function. The systems were so accurate, but inflexible, that the typical shipyard data bank could not support the rigorous demands of mathematically sound systems.

Failure could be traced directly to the use of historical data for input to the system/resource allocation model.

A very significant discovery of the 0-2 research team was that the failures which were experienced in use of improved production control systems in shipyards were not caused by the systems at all, but fell directly on the quality of the data being manipulated by the system. When data utilization was being done manually, management realized that his function required judgement and so a person of skill and knowledge in shipyard operations was assigned the job. Planners, schedulers and others within the production control group were often selected from the ranks of the more skilled craftsmen, or supervisors because of the high level of understanding these people had for the true nature of the shipbuilding process. They made the system work despite the weakness or inaccuracies in some of the information available to them.

In contrast, modeled production control systems were constructed in a very rigid manner. Variations in the input data which were acceptable to the manual systems caused tremendous difficulties to the model. As a consequence, many attempts at improving management control systems were abandoned as being impossible. From this one can conclude that the real thrust for 0-2 has to first be on how to improve the budget data available and secondly how to improve the preciseness of the planning rules used, both of which are needed to satisfy the computer requirement for refined and orderly data. A third item was identified as being a very desirable feature of any improved Planning and Production Control System. If any way could be developed to extend management's control over expenditures and

schedules, such an extension would have to make use of the Planning and Production Control System for effective implementation.

3. Survey Of Heavy Industry

Industries which used processes similar to those in shipbuilding (cutting, bending, assembly, welding, fabrication, etc.) were surveyed since they offered the best opportunity of learning about Planning and Production Control techniques that were successful and could be transferred to shipbuilding operations.

Three conclusions were reached from this survey:

1. Regardless of the management style of the top executive, he insisted that managers have greater control over operations than was generally required by shipyard management.
2. The Planning and Production Control function played a very central and strong staff role in the achievement of management goals.
3. Production control functions utilized accurate and detailed resource allocation data.

Let us consider each of these conclusions in turn:

It was clear to the researchers that the personality of the chief executive officer had a pronounced influence on the way that a firm operated. In the most successful businesses, this influence was one of style and emphasis. Changes in top management personnel did not tend to cause big changes in corporate systems, or in corporate procedures. Changes

were made in goals, but not usually in the ways of achieving these goals. Management control was exercised by all levels of management and usually was manifested in those operations where results could be quantified through the use of a definite, documented plan. For the first line supervisor, this meant that he was able to earn standard hours in proportion to the work that his crews performed. His actual expenditures for labor were then compared to the earned standard hours. His performance was measured by the variance between earned and expended hours. In some operations where results could not be quantified, a control plan was implemented to permit management by objectives. Non-labor items were usually measured by a technique which recorded earned units compared to actual units for the supervisor who had control over the expenditure. By keeping the measurement at the point of control, management at all levels motivated to higher performances.

In order to achieve management objectives, heavy industry had developed a systematic method to perform the Planning and Production Control function. This involved:

1. Reliable modeling rules for Planning to use in determining the manufacturing plan for the product to be produced.

2. Resource allocation rules which were consistent, reliable and trustworthy.

3. Performance measured in a timely manner at the point of management control with summary reports going to higher levels of accountability.

Let us examine these three points in greater detail to see if they offer a solution to the shipyard Planning and Production Control. problems outlined earlier.

Reliable Modeling Rules. In order to develop a viable production plan, Planning must know what product is being built. For preliminary plan development when the product design is less than complete, design data may be used. However, less than full accuracy will result and management must recognize this weakness. The preliminary plan is reworked as soon as the product design is complete. Shipbuilding seems to be the only industry where contracts with fixed prices and fixed milestones are signed before the end product is adequately designed.

Also, the production plan must be based on build methods which have been agreed to ahead of time and which will be employed for the construction cycle. Any changes in method must be evaluated before they are instituted, and if the new methods are superior to the old methods, the new methods become the new standards for future manufacturing. The resource allocation and the manufacturing plan are built upon the same base data for preliminary through final design. Consequently, reiterations can be tracked and reliability ascertained.

Reliable And Consistent Resource Allocation Rules. Whether the allocations are for budgets, for elapsed time at a work station, or man-hours for each member of a crew, each budget must be fair, equitable and consistent. Although the level is not correct (e.g., if everybody gets only 80% of

the-hours that are needed) but the level is consistent throughout the shipyard activities, then corrections can be made to adjust for the 20% error. However, if the level varies between manufacturing steps, or crafts, or products, the result is unmanageable chaos. Such budget allocations will not have the support of management, nor the confidence of the work force. Performance measurement to such a variable level would be unjust and would not allow any improvement in management control.

To have consistency in resource allocation, then, it is necessary to have budget units which are as small as the smallest allocation to be made. A large budget which results from a bid which is subsequently subdivided into a few work packages is not as satisfactory a budget as one would have if the bid budget were developed by summing up the associated work package. budgets. This method can not be used, however, unless the product is defined at the time of bid.

The budget rules should provide management with reliable information which has a known probable deviation from the absolute value of the budget. Shipyards have generally not recognized that the historical data which they collect and use for budgeting does not allow management to know what this deviation really is.

Budget rules should be objective, that is, the logic upon which they are built should be recorded and open to review. Changes in the rules should be based on objective evaluation of the alternatives. These rules and budgets can be systematized so that the answers provided (standard parts costs, production schedule dates, bid estimates, etc.) are consistent with the answers to the same questions from other sources.

Performance Measurement. This should be made in a time-frame which will permit corrective action. " There is nothing that can be done about costs if a ship is finished before the discovery that there has been an overrun.

Measurement should be made of those things which can be controlled. The amount of effort put into measurement should be commensurate with the value derived from the control. Measurement should be at the point of control and the person in control should be accountable for results. The furnace operator should know at what temperature the process furnac is operating. The thermocouple readout should be located ~t" the operator's station, not up in the President's office.

4. Summary

The comparison of the survey Of shipyards and of other industries led to the conclusions that:

- The potential for profit making is highest, in a. firm in which the management has the greatest control over expenditures.

  The implementation of that control Was tied very closely with the effectiveness of Planning and Production Control.

- The effectiveness of Planning and Production Control depends on reliable information about the product, manufacturing process, resource requirements and the actual expenditures:

t- in d ers

More generally, management in other industries has a firmly articulated hierarchy of schedule and budget targets

identified to each level in the management hierarchy (Figure C-2).

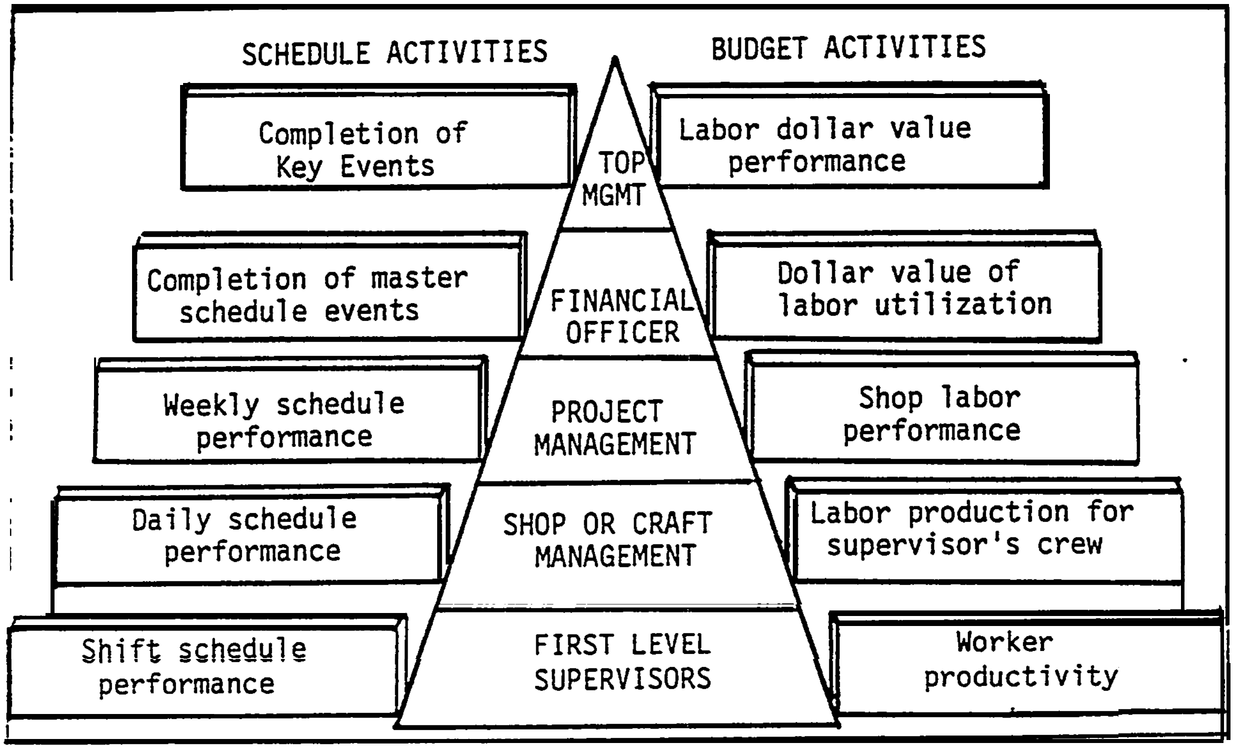

FIGURE C-2: SCHEDULE AND BUDGET ACTIVITIES
A direct correlation exists between level of management and level of activity accountability.

The O-2 task force determined that cost improvements for shipbuilding would be possible if a similar discipline could be imposed on the Planning and Production Control function. The most needed innovation was an improvement in the reliability of schedules and budgets. A new understanding had to be developed of the steps in the planning process. Section V of this report describes what was done to find this better way.